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97737

NASA Technical Paper 3536

October 1996

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Summary

Brush seals are compliant contacting seals and have significantly lower leakage than labyrinth seals in gas turbine applications. Their long life and low leakage make them candidates for use in rocket engine turbopumps. Brush seals, 50.8 mm (2 in.) in diameter with a nominal 127-μm (0.005-in.) radial interference, were tested in liquid nitrogen (LN_2) and liquid hydrogen (LH_2) at shaft speeds up to 35 000 and 65 000 rpm, respectively, and at pressure drops up to 1.21 MPa (175 psid) per brush. A labyrinth seal was also tested in liquid nitrogen to provide a baseline. The LN_2 leakage rate of a single brush seal with an initial radial shaft interference of 127 μm (0.005 in.) measured one-half to one-third the leakage rate of a 12-tooth labyrinth seal with a radial clearance of 127 μm (0.005 in.). Two brushes spaced 7.21 μm (0.248 in.) apart leaked about one-half as much as a single brush, and two brushes tightly packed together leaked about three-fourths as much as a single brush. The maximum measured groove depth on the Inconel 718 rotor with a surface finish of 0.81μm (32 μin.) was 25 μm (0.0010-in.) after 4.3 hr of shaft rotation in liquid nitrogen. The Haynes-25 bristles wore approximately 25 to 76 μm (0.001 to 0.003 in.) under the same conditions. Wear results in liquid hydrogen were significantly different. In liquid hydrogen the rotor did not wear, but the bristle material transferred onto the rotor and the initial 127-μm (0.005-in.) radial interference was consumed. Relatively high leakage rates were measured in liquid hydrogen. More testing is required to verify the leakage performance, to validate and calibrate analysis techniques, and to determine the wear mechanisms. Performance, staging effects, and preliminary wear results are presented.

Introduction

Brush seals are being tested in cryogenic fluids to determine their usefulness in cryogenic turbopumps for rocket engine systems. Successfully operated for thousands of hours in gas turbine applications, brush seals have shown a significant improvement in leakage performance over labyrinth seals (a 50- to 90-percent reduction initially and for long life applications, a 20- to 25-percent reduction, refs. 1 to 3). Their low leakage and long life make brush seals candidates for use in rocket engine turbopumps, particularly for space-based engines and reusable launch engines. The low leakage requirement is critical in meeting the wide-operating-range requirement of space engines in which seal leakage can significantly reduce engine performance at low thrust levels. Brush seals have also been shown to be more rotordynamically stable than labyrinth seals (ref. 4). Little brush seal data exist in the open literature and that which does has focused on gas applications (refs. 5 to 9). The first brush seal data taken in liquid nitrogen were obtained by Rocketdyne under a cooperative agreement with the NASA Lewis Research Center (ref. 10). This report will present liquid nitrogen and the first liquid hydrogen brush seal data known to be taken.

In a cryogenic turbopump, brush seals may be used to seal either liquid hydrogen or liquid oxygen at locations near the pump or the bearings, or they may be used to seal hot gaseous hydrogen, combustion gases, warm gaseous oxygen, or helium at locations near the turbine or purge seals. In this environment, large temperature gradients, oxygen compatibility, and hydrogen embrittlement are concerns. Also, shaft speeds can be quite high, up to 200 000 rpm for future upperstage rocket engine liquid hydrogen turbopumps. Because brush seals are compliant contacting seals, their wear rate and wear mechanism are important. To address the full range of conditions that a brush seal may be exposed to in a cryogenic turbopump, hot gas testing is also being done at the NASA Lewis Research Center (ref. 11).

The testing of brush seals in liquid nitrogen and liquid hydrogen was conducted at the NASA Lewis Research Center at shaft speeds up to 35 000 and 65 000 rpm, respectively, and at pressure drops up to 1.21 (175 psid) per seal. A labyrinth seal was also tested in LN_2 to provide a baseline for comparison. The apparatus, test procedures and operating conditions, calculations, and prediction tools are described. The results of the liquid nitrogen data presented and discussed include labyrinth seal and single brush seal steady-state performance, staging effects, and preliminary wear data. The hydrogen data presented are for a single brush and include steady-state performance and preliminary wear data.

Apparatus

Facility Description

Testing was conducted in cell 2 of the Cryogenic Components Laboratory (CCL) at the NASA Lewis Research Center. An aerial photograph of the CCL is shown in figure 1. The test cell, a 4.6- by 4.6-m (15- by 15-ft) expendable building with rollup doors on each side, housed the test article and the associated flow-control and instrumentation hardware. High-pressure liquid hydrogen (LH_2) or liquid nitrogen (LN_2) was fed into the test cell from an adjacent 4.92-m^3 (1300-gal), 9.93-MPa (1440-psig) run dewar. This tank was filled from either a 45.42-m^3 (12 000-gal) LH_2 low-pressure storage dewar or a 15.14-m^3 (4000-gal) LN_2 low-pressure storage dewar, depending on the fluid required, and then was pressurized with gas from two 16.55-MPa (2400-psig), 1982-m^3 (70 000-scf) gaseous hydrogen (GH_2) or gaseous nitrogen (GN_2) tube trailers, respectively. These two tube trailers also supplied GN_2 or GH_2 to the test rig turbine drive for the LN_2 and LH_2 tests, respectively. After flowing through the test rig, all fluids were vented to the hydrogen burnoff located behind the test cell. All system piping, shown schematically in figure 2, was helium and vacuum purged before each LH_2 test. Gaseous nitrogen was used as the purge gas for LN_2 testing. These tests were controlled remotely from the CCL control room and were monitored using several video cameras, an audio pickup, and the instrumentation systems.

Test Rig Description

The test rig is the Low Thrust Pump Tester designed by Rocketdyne under contract NAS3-23164 (ref. 12) and modified to test brush seals. A cross section of the test rig is presented in figure 3. Note that for clarity some of the ports are shown out of rotation. The Inconel 718 shaft is supported by two pairs of cryogenic ball bearings and is driven by an Astroloy full-admission axial-flow turbine on one end of the shaft. A 50.8-mm-(2.000-in.-) diameter seal runner is located on the opposite end of the shaft. Axial loads are supported by a self-compensating gas-fed balance piston located at the center of the shaft. Very little axial load is generated by the turbine; most of the axial load is a result of the pressure drop across the brush seal. The balance piston can support axial loads due to a pressure drop across the seal of up to 2.07 MPa (300 psid). Intercavity sealing along the shaft is accomplished using several labyrinth seals.

The tester can accommodate from one to five brush seals in a variety of spacing configurations. The seal holder is 304 stainless steel. Two different Inconel 718 seal runners with a 0.81-μm (32-μin.) surface finish were used: a long, low-speed runner and a short, high-speed runner. The low-speed runner can accommodate all five brushes at one time but is limited to 40 000 rpm to stay below the predicted first critical speed of 45 000 rpm. The high-speed runner, a shortened version of the low-speed runner, accommodates just one seal but can be operated at speeds up to 70 000 rpm, the predicted first critical speed.

Liquid hydrogen or liquid nitrogen was supplied to the inboard, high-pressure side of the runner at pressures up to 5.52 MPa (800 psig), the maximum allowable working pressure of the rig. This supply fluid then passed through a perforated plate, which is integral with the test-seal-end labyrinth seal, to steady the flow. In tests where leakage through the brush seal was low, it was necessary to bypass some flow out of the brush seal supply cavity to keep the rig cold enough. Liquid hydrogen or liquid nitrogen was also supplied to the bearings for coolant. Photographs of the test cell with the rig installed and after it had been chilled are shown in figures 4 and 5, respectively.

Test Hardware

Brush seals are compliant contacting seals. Figure 6 shows a typical brush seal, which comprises a ring-shaped pack of small-diameter wire bristles set at an angle to the radial direction and sandwiched between a front and back washer. The back washer is on the low-pressure side of the seal and serves as a mechanical support to prevent the bristles from bending downstream as a result of the pressure load. Typically, the bristles are designed to have a 127.0- to 254.0-μm (0.0050- to 0.0100-in.) radial interference with the shaft. Brush seals with an interference leak less than those with a line-to-line or clearance fit (ref. 8). The bristles are angled, usually 30° to 60° and thus act as cantilevered beams. Because of their initial interference with the shaft, the bristles are preloaded and tend to follow the shaft during rotordynamic excursions. The degree to which the bristles follow the shaft, or the frequency response, is important and depends on the radial stiffness of the bristles and mass.

The nominal geometry of the brush seal and runner configurations tested is shown in figure 7. The Inconel 718 seal runner was 50.8 mm (2.000 in.) in diameter and had a surface finish of 0.81 μm (32 μin.) on its outer diameter. The Haynes-25, 0.071-mm- (0.0028-in.-) diameter bristles had a 40° angle to the radius, were packed at a density of 3000 bristles/in.-circumference of bore diameter, and had a 127-μm (0.005-in.) nominal radial interference with the runner. The outside diameter of the brushes was 71.60 mm (2.8190 in.) and the axial thickness was 3.61 mm (0.142 in.). Both the front and back washers were made of Hastelloy-X and were 1.42 mm (0.056 in.) thick. The radial clearances between the front and back washers and the runner were 5.08 and 0.279 mm (0.200 and 0.011 in.), respectively. Because there was some slight variation in geometry from brush to brush, the pretest inspection measurements are given in table I. The materials were chosen because they were compatible with liquid nitrogen and hydrogen. The Haynes-25 cobalt-base alloy was used for the bristles because it could

TABLE I.—PRETEST INSPECTION MEASUREMENTS OF BRUSH SEALS AND RUNNERS

Seal identification number	Inside diameter						Outside diameter		Axial thickness					
	Front washer		Bristles		Back washer				Front washer		Back washer		Entire seal	
	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
1	61.06	2.404	50.60	1.992	51.44	2.025	71.63	2.8200	1.35	0.053	1.52	0.060	3.620	0.1425
2	61.01	2.402	50.57	1.991	51.48	2.027	71.62	2.8197	1.42	.056	1.45	.057	3.627	.1428
3	61.11	2.406	50.47	1.987	51.38	2.023	71.59	2.8185	1.37	.054	1.37	.054	3.607	.1420
4	60.99	2.401	50.47	1.987	51.44	2.025	71.60	2.8190	1.45	.057	1.40	.055	3.632	.1430
5	61.19	2.409	50.57	1.991	51.44	2.025	71.59	2.8187	1.37	.054	1.50	.059	3.627	.1428
6	61.04	2.403	50.55	1.990	51.44	2.025	71.59	2.8187	1.40	.055	1.40	.055	3.569	.1405

Seal identification number	Radial distance between back washer inside diameter and—				Ambient interference with runner[a]		Bristle				
	Bristle inside diameter		Runner outside diameter				Height[b]		Diameter		Angle, deg
	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	
1	0.419	0.0165	0.320	0.0126	0.099	0.0039	5.232	0.2060	0.071	0.0028	37
2	.457	.0180	.345	.0136	.102	.0040	5.220	.2055			30
3	.457	.0180	.295	.0116	.163	.0064	5.321	.2095			25
4	.483	.0190	.320	.0126	.163	.0064	5.258	.2070			38
5	.432	.0170	.320	.0126	.102	.0040	5.309	.2090			34
6	.444	.0175	.315	.0124	.127	.0050	5.245	.2065			34

[a]Low-speed runner 1 used with seals 1 to 5. High-speed runner 1 used with seal 6. Low-speed runner 1 o.d.: 50.792 to 50.794 mm (1.9997 to 1.9998 in.); high-speed runner 1 o.d.: 50.808 mm (2.0003 in.).

[b]Radial length of bristle from front washer inside diameter.

be drawn; the wire diameter was determined by the available die.

Spacers used to study staging effects had the same overall dimensions as the brush seals and an inside diameter that was the same as the front washer inside diameter. Some spacers had radial holes located to match the instrumentation holes in the housing so when that spacer was used, 1.6-mm- (0.06-in.-) diameter thermocouples and pressure tubes could be installed to obtain interstage fluid conditions. Seal positions and instrumentation stations are defined in figure 8(a). Instrumentation was always installed at the entrance and exit of the brush seal cavity, stations 1 and 5, respectively. Figure 8(b) displays the circumferential orientation of the instrumentation.

Configurations Tested

Nine seal configurations were tested and are described in table II. Configurations 1 to 8 were tested in LN_2 and configuration 9 was tested in LH_2. Configuration (1) was a 12-tooth, 127-μm- (0.005- in.-) radial-clearance labyrinth seal tested as a baseline with the low-speed rotor in LN_2. Its axial length is equivalent to five brushes tightly packed, and its geometry is shown in figure 9. The other configurations were (2) a single brush, (3) two brushes spaced far apart (7.21 mm (0.284 in.), two brush widths between), (4) two brushes tightly packed, and (5) three brushes evenly spaced 3.607 mm (0.142 in., or one brush width between) were tested. Tests of configurations 3 and 5 were repeated and are identified as 6 and 7 in table II: two brushes spaced 7.21 mm (0.284 in.) apart and three brushes evenly spaced. They were repeated because of a problem with the interstage pressure measurements, which is explained in the next section. Then, (8) a single brush was tested to measure static seal performance above 1.21 MPa (175 psid). Finally, in configuration 9, a single brush was tested with the high-speed runner in LH_2.

Instrumentation

The steady-state temperature, pressure, and flow rate of all fluids supplied to the tester were measured along with the seal leakage flow rate and all tester exit temperatures and pressures (see fig. 2). Metal strain gage transducers were used for all pressure measurements. Gold-iron/chromel and chromel/constantan thermocouples were used in the cryogenic liquid

TABLE II.—SEAL CONFIGURATIONS TESTED

Configuration number	Description	Seal position					Seal runner	Test fluid
		1	2	3	4	5		
1	12-tooth labyrinth	All positions					Low speed	LN_2
2	Single brush	Seal 2	----	----	----	----		
3	Two brushes far apart	----	Seal 3	----	----	Seal 4		
4	Two brushes tightly packed	----	----	Seal 1	Seal 5	----		
5	Three brushes evenly spaced	Seal 1	----	Seal 4	----	Seal 5		
6	Two brushes far apart; pressure taps at spacer i.d.	----	Seal 3	----	----	Seal 4		
7	Three brushes evenly spaced; pressure taps at spacer i.d.	Seal 1	----	Seal 4	----	Seal 5		
8	Single brush; blowout test	Seal 2	----	----	----	----		
9	Single brush	Seal 6	----	----	----	----	High speed	LH_2

systems and gaseous systems, respectively. All flow rate measurements were made using venturis. Venturis of two different sizes were used in series to measure the brush seal leakage rate.

Four pressure and four temperature measurements each were taken at stations 1 and 5. Two pressure and two temperature measurements could be taken at each of the interstage instrumentation stations 2, 3 and 4. Instrumentation at stations 1 through 5 was located 38 μm (0.0015 in.) from the seal runner in configurations 1 and 2. After testing configuration 2, some thermocouple damage was found and the seal instrumentation was moved back to 76 μm (0.003 in.) from the seal runner. The damage was attributed to insufficient support of the tip in a high flow, causing the tips to bend and break. The interstage pressure tubes were pulled back to the inner diameter of the spacer for configurations 6 and 7 because significant differences between pressure measurements at the same station occurred in configurations 3 and 5 and appeared to be speed dependent. These differences were not seen when the pressure tubes were located at the spacer inside diameter and are thought to be caused by a flow disturbance induced by the pressure tube.

Three eddy-current proximity probes located at 40°, 130°, and 220° were used to monitor seal runner orbits (see fig. 8(b) for orientation). Oscilloscopes displayed the orbits in real time. Two eddy-current proximity probes were used to monitor shaft speed at the single-notched balance piston. Another eddy-current proximity probe was used to monitor the axial shaft motion at the balance piston. An accelerometer was mounted on the seal end of the tester housing to measure radial acceleration to monitor the health of the tester. A complete instrumentation list can be found in appendix A.

Data Acquisition

All steady-state data were recorded using an Escort II data acquisition system that has a sampling rate of 10 kHz. The Escort II system acquires the millivolt data, converts it to engineering units, makes real-time calculations, displays the information on CRT monitors in the control room, and stores the data to the data collector for legal tape storage. The update time is 2 sec. For each steady-state condition, 10 scans of data were recorded. All scans during the static performance test were recorded. Once recorded, the data were sent to the scientific VAX cluster for postprocessing.

Dynamic data from the eddy-current proximity probes and accelerometer were recorded on a 14-channel FM tape recorder. The time code was recorded on channel 14 to enable correlation of the dynamic data with the steady-state data. A bandwidth of 62.5 kHz was used with a tape speed of 381 mm/sec (15 in./sec). Capacitors (1 μF) filtered out the dc offset of the proximity probe signals to bring them into the 1.0-V peak range of the tape recorder. Four oscilloscopes were used to monitor seal runner orbits, vibration, and speed signals.

In addition to the Escort CRT monitors and oscilloscopes, digital panel meters were used to display certain control and abort parameters, as shown in figure 10. A stop-shaft-rotation abort would be triggered by any of the following conditions: excessive shaft speed, excessive axial shaft motion, or excessive pressure at the turbine inlet.

Test Procedure and Nominal Operating Conditions

After the appropriate facility purges and setup, the seal tester was chilled down by flowing the cryogenic test fluid to the bearings and seal cavities. When liquid temperatures in the tester had been reached, approximately 77.8 K (140 R) for LN_2 and 27.8 K (50 R) for LH_2, testing began. Nominal inlet pressures were 5.38 to 5.5 MPa (780 to 800 psig) for LN_2 and 2.8 to 3.4 MPa (400 to 500 psig) for LH_2 tests. The outlet pressure of the seal was kept well above the critical pressure to avoid two-phase flow. The pressure drop across the seal package was set by controlling the backpressure on the seal cavity. Temperatures throughout the tester were monitored closely. A significant temperature rise indicated that the test fluid had run out.

Labyrinth Seal LN_2 Tests

System checkout tests were conducted with the labyrinth seal installed in the tester. A maximum shaft speed of 38 000 rpm was obtained at zero pressure drop across the seal. At 0 rpm, a maximum pressure drop across the seal of 2.24 MPa (325 psid) was obtained. Baseline leakage performance of the labyrinth seal was measured for pressure drops across the seal of 0.17 to 2.07 MPa (25 to 300 psid) at shaft speeds of 0, 5, 15, 25, and 35 krpm. A few intermediate test conditions at 10, 20, 30, and 31 krpm were also recorded, as indicated in table III(a).

Brush Seal LN_2 Tests

Prior to any shaft rotation, the LN_2 brush seal leakage rate was measured for increasing and then decreasing pressure drops across the seal of 0, 0.17, 0.52, 0.86, 1.03, 1.21, 1.03, 0.86, 0.52, 0.17, and 0 MPa (0, 25, 75, 125, 150, 175, 150, 125, 75, 25, and 0 psid). Then the pressure drop across the seal was set to 0.17 MPa (25 psid) and the shaft speed was increased to 5000 rpm. Again, data were taken for increasing and decreasing pressure drops across the seal in the same order and at the same levels as at 0 rpm, with the exception of the 0-MPa (psid) point. Because of balance piston limitations, the 0-MPa (psid)

TABLE III.—TEST MATRIX FOR LABYRINTH AND BRUSH SEALS IN LIQUID NITROGEN AND IN LIQUID HYDROGEN

(a) Labyrinth seal in liquid nitrogen

Seal pressure drop		Shaft speed,[a] rpm								
MPa	psid	0	5000	10 000	15 000	20 000	25 000	30 000	31 000	35 000
0	0			√		√		√		√
0.17	25	√	√		√		√		√	√
0.52	75	√	√		√		√		√	√
0.86	125	√			√		√	√		√
1.03	150	√	√		√		√	√		√
1.38	200		√		√		√			
1.65	225	√	√		√		√			√
2.07	300	√	√	√	√		√			√
2.24	325	√								

[a]Shaft speeds of 34 000, 37 000, and 40 000 rpm were also tested.

(b) Single brush seal in liquid nitrogen

Seal pressure drop		Shaft speed, rpm								
MPa	psid	0	5000	0	15 000	0	25 000	0	35 000	0
0	0	√		√		√		√		√
0.17	25	√	√	√	√	√	√	√	√	√
0.52	75	√	√	√	√	√	√	√	√	√
0.86	125	√	√	√	√	√	√	√	√	√
1.03	150	√	√	√	√	√	√	√	√	√
1.21	175	√	√	√	√	√	√	√	√	√
1.03	150	√	√	√	√	√	√	√	√	√
0.86	125	√	√	√	√	√	√	√	√	√
0.52	75	√	√	√	√	√	√	√	√	√
0.17	25	√	√	√	√	√	√	√	√	√
0	0	√		√		√		√		√

condition could not be reached during shaft rotation. The shaft was then brought down to 0 rpm and data were taken as the pressure drop was varied from 0 to 1.21 to 0 MPa (0 to 175 to 0 psid). Data were taken in a similar manner for 15 000-, 0-, 25 000-, 0-, 35 000-, and 0-rpm shaft speeds. The repeated data at 0 rpm were taken to determine if wear of the brush or runner had occurred. The specific test conditions for the single brush seal (configuration 2) are given in table III(b). For multiple brush configurations, the procedure was the same, except that the maximum total pressure drop was greater—up to 1.9 MPa (275 psid). However, the pressure drop across any individual brush seal did not exceed 1.21 MPa (175 psid). Each test condition was held for approximately 80 sec.

An additional static seal performance test was conducted for a single brush in LN_2. The purpose of the test was to determine the leakage performance for high-pressure (>1.21 MPa or 175 psid) drops across the seal and to verify that a seal blowout would not occur. The expected indication of a seal blowout, a condition in which the bristles bend downstream and lift off the shaft, is a sudden increase in leakage rate. After the tester was chilled down, a 0.59-MPa (85-psid) pressure drop across the seal was applied and the shaft speed was increased to 5000 rpm. At this low speed, the pressure drop across the seal was increased to 1.2 MPa (170 psid) and then decreased to 0.59 MPa (85 psid). Next, the shaft speed was brought to zero, and then the pressure drop across the seal was brought to zero. This sequence was used to properly seat the seal before starting the static performance test. At 0 rpm, while data were continually recorded, the pressure drop across the seal was increased to a maximum of 4.6 MPa (670 psid). Then the pressure load was gradually removed. Unfortunately, the leakage rate instrumentation reached a maximum limit at 3.8 MPa (550 psid) across the seal.

Brush Seal LH_2 Tests

Only configuration 9, a single brush on the high-speed runner, was tested in LH_2. The procedure for the LH_2 tests was somewhat different from that for the LN_2 tests; primarily, the differences were that the high-shaft-speed data were taken first and the maximum shaft speed was 65 000 rpm.

First, to check out the system and obtain baseline leakage data for the seal, the pressure drop across the seal was varied from 0 to 1.21 MPa (0 to 175 psid) and then decreased to 0 MPa (0 psid) at a shaft speed of 0 rpm. Second, tests were conducted to determine the maximum shaft speed for the high-speed seal runner. At a pressure drop across the seal of 0.52 MPa (75 psid), the speed was increased and data were recorded at 15, 25, 35, 45, 55, 65, and 75 krpm. A maximum shaft speed of 65 000 rpm was chosen to conduct the seal leakage performance tests. At 65 000 rpm the pressure drop across the seal was varied and data were taken in the order of the following conditions: 0.52, 0.69, 0.83, 1.08, 1.21, 1.08, 0.83, 0.69, 0.52, and 0.17 MPa (75, 100, 121, 156, 175, 156, 121, 100, 75, and 25 psid). This speed and these pressure conditions were selected to match the design conditions of the brush seal to be used in the Advanced Expander Test Bed LH_2 turbopump (ref. 13). The shaft speed was then decreased to 0 rpm and data were taken as the pressure across the seal varied from 0.17 to 1.21 MPa (25 to 175 psid) and then decreased to 0 MPa (0 psid). Data were then taken at shaft speeds of 55 000, 0, 45 000, 35 000, 25 000, 15 000, and 0 rpm at the pressure conditions given in table III(c). Again, each test condition was held for approximately 80 sec.

Calculations

With the exception of the static performance test data, all data presented are an average of 10 scans. Prior to averaging, each scan was reviewed to ensure that steady-state conditions existed and that averaging was appropriate. The temperatures and pressures at each seal instrumentation station were also averaged. Pressure and temperature differences between stations were calculated from average values. Standard venturi equations were used to calculate flow rates (ref. 14). Actual fluid properties were obtained from the program FLUID (ref. 15). To account for variations in inlet conditions, a parameter called RODPab was calculated. RODPab is the inlet density at station a multiplied by the pressure difference between station a and station b. The power loss across the seal was calculated as the seal leakage mass flow rate multiplied by the enthalpy difference of the fluid across the seal. The measurement uncertainties of key seal performance parameters were calculated and are presented in appendix B.

Prediction Tools

Computer analysis codes were used to predict the performance of the labyrinth and brush seals. The code used to predict the labyrinth seal performance was developed at Texas A & M University under NASA Contract NAS8-34536. The code calculates mass leakage rate for incompressible fluids in straight-through labyrinth seals using Dodge's formula and interpolating experimental data (ref. 16). In making the leakage predictions with this code, the measured fluid conditions were used for each data point. The fluid properties data required for input were obtained using a program called GASPROPM, a user-friendly front end for the fluid properties routine called FLUID (ref. 15).

Analysis techniques to predict brush seal leakage performance are less developed than those used for labyrinth seal analysis. The brush seal is more difficult to model because of its compliant and permeable nature. Theories developed for crossflow in tube bundles and for flow-through porous mediums have been applied to brush seals to account for the flow resistance of packed, compliant bristles.

Chupp, Holle, and Dowler (ref. 17) developed a simple flow model that uses a single parameter, effective brush thickness, to correlate flow through the seal. The underlying model is based

TABLE III.—Concluded.

(c) Brush seal in liquid hydrogen

Seal pressure drop		Shaft speed,[b] rpm									
MPa	psid	0	65 000	0	55 000	0	45 000	35 000	25 000	15 000	0
0.07	10	√									
0.10	15					√				√	√
0.17	25	√		√	√	√	√	√	√	√	√
0.34	50	√									
0.52	75	√	√	√	√	√	√	√	√	√	√
0.69	100	√	√								
0.83	121		√								
0.86	125	√		√	√	√	√	√	√	√	√
1.03	150	√			√	√	√	√	√	√	√
1.08	156		√								
1.21	175	√	√	√	√	√	√	√	√	√	√
1.08	156		√								
1.03	150	√			√	√	√	√	√	√	√
0.86	125	√		√	√	√	√	√	√	√	√
0.83	121		√								
0.69	100	√	√								
0.52	75	√	√	√	√	√	√	√	√	√	√
0.34	50	√									
0.17	25	√	√	√	√	√	√	√	√	√	√
0.10	15				√	√		√	√		√
0.07	10	√									
0	0	√				√					√

[b]At each shaft speed, data were taken at seal pressure drops as listed from top to bottom; shaft speeds were run in sequence as listed from left to right.

on crossflow through staggered tubes. The simple model reveals the active nature of a brush seal as the pressure drop changes. A more comprehensive flow model was proposed by Hendricks et al. (ref. 18). Hendricks' bulk flow model is also based on theory that deals with crossflows in bare and extended tubes. This brush seal flow model predicts leakage rates by using brush seal geometry, seal pressure drop, and fluid transport properties as inputs. Hendricks reported that the model predicted trends and general levels reasonably, but at low flows and low pressure drops, the model deviated from experimental data provided by Cross Manufacturing.

Another approach, proposed by Chew from Rolls Royce, suggested the use of the Ergun equation:

$$\Delta P = aq + bq^2 \tag{1}$$

where ΔP is the pressure drop across the seal; a and b are coefficients; and q is the volumetric flow rate. The equation was originally formulated to predict fluid flow through porous materials. The permeability of the brush seal bristles can be considered a porous medium. However, the bristle compliancy complicates the flow problem and is not captured by the Ergun equation. On the other hand, in a letter to Hendricks (J.W. Chew, Rolls-Royce Aerospace Group, P.O. Box 31, Derby DE288J, England, October, 27, 1992), Chew's prediction showed good correlation with data provided by Hendricks (ref. 19). Hendricks has further investigated the use of the Ergun equation and has developed relations for the coefficients used in the equation (ref. 20). He proposed that the coefficients be a function of brush porosity, brush thickness, bristle diameter, fluid viscosity, density, and turbulence friction factor. Predictions from Hendricks, Flower, and Howe (ref. 20) showed good correlation with gaseous helium, air, argon, and carbon dioxide brush seal data obtained by Carlile, Hendricks, and Yoder (ref. 19). When Hendricks applied the Ergun equation to data for brush seals tested in liquid nitrogen (ref. 10), the correlation was not as good.

Kudriavtsev and Braun (ref. 21) proposed solving the continuity and momentum equations for flow patterns around sets of pins to simulate flow patterns in brush seals. To reduce computer memory and power requirements necessary to model a full brush seal, Kudriavtsev suggested using representative segments. A few columns and rows of bristles may adequately represent a whole seal if proper boundary conditions are specified. In addition, Kudriavtsev assumed that the first and last couple rows of bristles for a brush seal of 10 or more rows could be neglected because they tend to spread and do not significantly effect the fluid pressure drop. Kudriavtsev explored this approach and reported that it was feasible. Much work, however, is still needed to fully develop it.

The proposed models have been developed mainly for gas brush seals because gas turbine engines are the prime applications. Consequently, ample gas brush seal data are available. However, little data exist for brush seals operating in liquid environments. Although gradually changing, there are insufficient data to calibrate and validate the brush seal models for liquid applications. Because more experimental data are required, no analytical comparisons are presented.

Results and Discussion of LN_2 Tests

Temperature, pressure, speed, and leakage rate data for all configurations are presented in appendixes C and D in SI and English units, respectively.

Labyrinth Seal Performance

A 12-tooth, 127-μm- (0.005-in-.) radial-clearance labyrinth seal was tested in liquid nitrogen to establish a baseline for comparison. The measured and predicted mass leakage rates of the labyrinth seal are shown in figure 11 as a function of the inlet density ρ multiplied by the pressure drop ΔP across the seal for all shaft speeds tested. The pressure drop across the seal was multiplied by the inlet density to account for the variation in the inlet conditions from test to test. The data show no appreciable speed effect on the leakage rate, and the measured and predicted leakage rates are of the same magnitude and trend, increasing with increased $\rho\Delta P$.

Single Brush Seal Performance

The leakage performance of a single brush seal in liquid nitrogen located in position 1 of the seal cartridge is shown in figure 12. Again, mass leakage rate is plotted as a function of the inlet density multiplied by the pressure drop across the seal for all shaft speeds. It is interesting to note that the first leakage rate data taken at 0 rpm is approximately 1.7 times greater than all the other data. This phenomenon was seen in each new configuration and indicates that both a pressure load and shaft rotation are required to seat the seal bristles into their optimum position. Although the leakage data for the different shaft speeds exhibit some variation, there is no distinct speed dependence. However, the leakage rate at the end of the test was approximately double that measured at the beginning, which indicates that wear had occurred. Figure 13 compares the leakage performance of the labyrinth and the brush seals and shows that the single brush seal had a mass leakage rate of one-half to one-third that of the 12-tooth labyrinth seal with a radial clearance of 127 μm (0.005 in.).

Figure 14 shows fluid temperature rise across a single brush seal in liquid nitrogen between stations 1 and 3 as a function of $\rho\Delta P$ for the shaft speeds tested. As expected, the fluid temperature rise is greater at higher shaft speeds, mainly because of higher frictional heating. The fluid viscous shear forces also generate more heat at higher shaft speeds. The temperature rise decreases for increased $\rho\Delta P$ because there is more coolant flow to carry the heat away.

The results of the static seal performance test are shown in figure 15 in which leakage rate is plotted as a function of $\rho\Delta P$. A pressure drop across the seal of 3.8 MPa (550 psid) was obtained with no evidence of blowout occurring.

The power loss for a single seal in position 1 was calculated as the product of the seal mass leakage rate and the fluid enthalpy change from station 1 to station 2. In figure 16 the power loss is plotted as a function of the shaft speed for several ΔP values. Although higher ΔP conditions appear to increase power loss slightly, the variation is within the uncertainty of this calculation. The uncertainty is strongly influenced by the sensitivity of enthalpy to temperature changes. Power loss is, however, a function of speed cubed. The maximum power loss measured for a single brush was 1826 W (2.45 hp) at 35 000 rpm and a pressure drop across the seal of 1.21 MPa (175 psid). Labyrinth seal power loss measurements are not provided for comparison because the thermocouples at station 5 were located in a relatively large cavity and were exposed to environmental heat loads not attributable to the seal.

Staging Effects

Staging effects on leakage rate are significant, as seen in figure 17. In this figure, the leakage rate at a shaft speed of 5000 rpm is plotted against $\rho\Delta P$ for a single brush, for two brushes far apart (7.21 mm or 0.284 in.), and for two brushes tightly packed. The leakage rate for two brushes far apart is approximately one-half that of the single brush leakage rate. However, the leakage rate for two brushes tightly packed is approximately three-fourths that for the single brush seal. This phenomenon of two brushes far apart leaking less than two brushes tightly packed occurred at all shaft speeds (5, 15, 25, and 35 krpm). Additional brushes caused the fluid temperature rise across the seal to increase because the added brushes caused more frictional heating. Figure 18 compares the fluid temperature rise between stations 1 and 5 for one, two, and three brushes as a function of $\rho\Delta P$ at 35 000 rpm. The maximum temperature rise of approximately 53 K (95 R) occurred for three brushes at the lowest $\rho\Delta P$ value, which is also the lowest flow rate. It is important to note that the fluid temperature measured at station 5 is really that of the seal leakage mixed with the fluid in the exhaust cavity, which tends to be somewhat warmer. Therefore, the actual temperature rise is something less than the values shown in figure 18.

The pressure load distribution in a multistage configuration appears to be affected by shaft speed. Plots of leakage performance versus $\rho\Delta P$ for individual brushes and for all brushes together in the configuration three brushes evenly spaced are shown in figures 19 and 20 at 0 and 35 000 rpm, respectively. At 0 rpm, the first and second brushes each carried approximately 25 percent of the total pressure drop across the seal, and the third brush seal carried the remaining 50 percent. At 35 000 rpm, each of the three brushes carried approximately equal portions of the total pressure drop. A review of the data at 5, 15, and 25 krpm shows a gradual transition of the pressure load distribution between 0- and 35 000-rpm shaft speeds.

Preliminary Wear Data

Brush seal wear is affected by many parameters: material properties and combination, surface finish, geometry, shaft speed, friction coefficient, shaft rotordynamics, initial interference, and coolant flow. The Inconel 718 rotor had a surface finish of 0.81 μm (32 μin.). Shaft rotordynamics were very good with a nominal seal runner orbit of less than 5 μm (0.0002 in.) in diameter. A maximum seal runner orbit diameter of 25 μm (0.001 in.) occurred at 35 000 rpm for a short period of time when the pressure drop across the seal was being adjusted. No significant vibration was observed. The maximum shaft speed was 35 000 rpm, which translates to a surface velocity of 93 m/sec (305 ft/sec). Again, the bristle material was Haynes-25.

Seal runner wear did occur as evidenced by the tracks found during posttest inspection. A scanning electron microscope (SEM) photograph of the tracks is shown in figure 21. To measure runner wear, profilometer traces were taken across the axial length of the runner at four circumferential locations: 0°, 90°, 180°, and 270°. The profilometer trace at 0°, taken after testing configuration 4 before any track was reused, is shown in figure 22. The final profilometer trace, taken after testing configuration 7, is shown in figure 23. The maximum groove depth measured was 25 μm (0.0010 in.) and the nominal groove depth measured was 19 μm (0.00075 in.) after 4.31 hr accumulated shaft rotation time. A plot of the maximum groove depth of each track as a function of time is shown in figure 24. The maximum, minimum, and average values of the maximum groove depth measurements are shown. Tracks 1 and 3 show first an increase and then a decrease in groove depth with time. Track 5 shows a decrease in groove depth with time but reveals variations in the depth measurement of 11 μm (4.5×10^{-4} in.). The other tracks have a variation in the groove depth measurement of approximately 3 μm (1.2×10^{-4} in.). The wear tracks had an axial width up to 1.2 mm (0.049 in.). This is larger than the bristle pack width of 0.76 mm (0.0298 in.). The difference between the bristle pack width and the track width is greater than the measured axial motion of the shaft of 0.51 mm (0.020 in.). Because there was some axial motion so that the brushes did not run over the exact spot on the runner all the time and because the shaft speed varied, it is valuable to look at wear rate in terms of groove area and distance, as shown in figure 25. This view of the wear data shows more consistently an increase in wear with an increase in distance. The maximum distance was 805 km (2.64 million ft).

The bristles also show wear of approximately 25 to 76 μm (0.001 to 0.003 in.). Bristle wear is difficult to quantify because of uncertainty in the bristle bore diameter measurement. An optical comparator was used to measure the inner diameter of the brush seals and, depending on the exact circumferential location and the person taking the reading, variations of 191 μm (0.0075 in.) were found. These measurements were also affected by unevenness of the bristles, as shown in figure 26. Early in the test matrix, approximately 10 bristles showed evidence of some melting (see fig. 27). Melted bristles were first found after running high-speed conditions with no ΔP across the seal. This implies that some leakage is necessary to cool the bristles and that high-temperature bristle materials may need to be used. Once bristle melting was discovered, these high-speed and no-flow test conditions were discontinued. It also appears that the wear is substantially more on the downstream bristles than on the upstream bristles, as shown in figure 28. The bristles in region A are the downstream bristles that are close to the back washer and show a smearing-type wear. Bristles in region B show little, if any, wear.

Results and Discussion of LH_2 Tests

Performance Data

The leakage performance of a single brush in liquid hydrogen at all speeds tested is shown in figure 29 and is compared with the predicted leakage performance of a 12-tooth, 127-μm-(0.005-in.-) radial-clearance labyrinth seal at 0 and 65 000 rpm. Unlike the liquid nitrogen data, the brush seal leakage performance is not significantly better than the predicted labyrinth seal leakage performance, and a speed effect is present. As speed decreased from 65 000 to 35 000 rpm, the leakage rate decreased slightly. Then a jump occurred at 25 000 rpm, with the leakage rate increasing to values approximately 50 percent larger than the leakage rate at 65 000 rpm. As the speed decreased further to 15 000 rpm, the leakage rate again decreased but still remained higher than the data taken at 65 000 rpm. Although no definitive explanation for these observations can be given at this time, possible causes include wearing of the bristles and lifting away of the bristles from the shaft as a result of shaft orbits or aerodynamic effects. Other studies have found that bristle hysteresis and stiffening effects can significantly affect seal performance (ref. 22), and it is likely that these are contributing factors. The final data taken at 0 rpm has leakage rates one-half to one-third of the predicted labyrinth seal leakage rates. More data need to be taken to confirm this result. It is possible that the bristles relaxed and packed themselves more tightly when the pressure drop across the seal was decreased to 0.07 MPa (10 psid).

As shown in figure 30, the fluid temperature rise between stations 1 and 2 at all speeds and $\rho\Delta P$ values was minimal, with a maximum temperature rise of approximately 11 K (20 R). Although this is substantially less than the temperature rise in liquid nitrogen, it is not surprising. Comparing the nominal inlet conditions of LH_2 and LN_2 reveals that the specific heat of hydrogen is approximately five times greater than that of liquid nitrogen.

The power loss of a single brush seal in liquid hydrogen is shown in figure 31 as a function of shaft speed for two pressure drops across the seal, 1.21 and 0.52 MPa (175 and 75 psid). As observed in the liquid nitrogen data, the higher pressure drop across the seal has a slightly higher power loss and the power loss is a function of speed cubed. The maximum power loss in liquid hydrogen was 2180 W (2.92 hp) and occurred at 65 000 rpm at a pressure drop across the seal of 1.21 MPa (175 psid). As expected, the power loss in liquid nitrogen was greater than in liquid hydrogen largely because of the greater viscosity and lower specific heat of liquid nitrogen. Specifically, the power loss in LN_2 is 1827 W (2.45 hp) and in LH_2 is approximately 634 W (0.85 hp) at 35 000 rpm at a ΔP of 1.21 MPa (175 psid).

Preliminary Wear Data

The bristle and seal runner materials were the same as those used in the liquid nitrogen tests: Haynes-25 bristles and Inconel 718 runner. The shaft rotordynamic excursions were small, with a maximum orbit diameter of 57 μm (0.00225 in.) occurring at 65 000 rpm (a surface velocity of 172.9 m/sec or 567.2 ft/sec). It should be noted that during system checkout testing there were two occurrences of momentary overspeeds in excess of 80 000 rpm. A total of 1.8 hr of shaft rotation time was accumulated. This is a linear distance of 869 km (2.85 million ft). Although the accumulated shaft rotation time in liquid hydrogen was less than in the liquid nitrogen tests, the accumulated linear distance was approximately 8 percent more.

Posttest examination revealed no wear of the runner but instead, a deposit of bristle material on the runner (shown in fig. 32). The bristle interference, 127 μm (0.005 in.) radially, had been totally consumed. This result is significantly different from the wear found in LN_2. However, there were two major differences in the tests. First, hydrogen is a reducing environment and nitrogen is inert. Second, the hydrogen testing was done at shaft speeds nearly double those of the nitrogen testing. Although intuition suggests that the shaft speed is more likely the key factor, further testing is required. An SEM photograph of the bristle tips (fig. 33) shows a smearing type of wear. Also, the outer bristles on each side of the brush pack were bent out axially whereas the bristles towards the center of the brush appeared to be uniformly packed, as shown in figure 34. The outer bristles also exhibited circumferential bending as well (see fig. 35).

Concluding Remarks

The compliant contacting nature of brush seals gives them a very small effective clearance. Both a pressure load and shaft rotation were required to initially seat the seal bristles in their optimum position. The measured liquid nitrogen (LN_2) leakage of a single brush seal was one-half to one-third the leakage of a 12-tooth labyrinth seal. Predictions of the labyrinth seal LN_2 leakage were in agreement with the measured data. The leakage performance of a single brush seal in liquid hydrogen (LH_2) was comparable to that in liquid nitrogen. However, the LH_2 leakage was expected to be less because of the lower density of LH_2. In comparison with predicted LH_2 leakage performance for a 12-tooth, 127-μm- (0.005-in.-) radial-clearance labyrinth seal, the single brush leakage was the same. Also, in LN_2, leakage did not depend on shaft speed but in LH_2, a speed dependence was observed. It is possible that significant wear occurred early in the LH_2 tests and that the bristles lifted off the rotor. Another possible explanation for this observed speed dependence is that LH_2 testing was conducted at higher shaft speeds where shaft orbits were larger and that a clearance opened between the bristles and the runner. This may be combined with a hysteresis effect. Hysteresis effects have been observed in hot gas brush seal studies. During LH_2 testing, the pressure load on the seal was not reduced to nearly zero between each shaft speed tested, as done in the LN_2 testing.

As expected, the fluid temperature rise across the seal is a function of the leakagé rate and the shaft speed. A pressure drop across the seal of 3.8 MPa (550 psid) was applied at 0 rpm with no blowout of the seal. The pressure capability of brush seals is certainly a function of the seal geometry and may be quite high. However, further testing is needed at both static and rotating conditions. The power loss in LN_2 was greater than in LH_2 because of the greater viscosity of LN_2. However, in either fluid the power loss was small: 1827 W (2.45 hp) in LN_2 and 634 W (0.85 hp) in LH_2 at 35 000 rpm at a pressure drop across the seal of 1.21 MPa (175 psid). The maximum power loss in LH_2 was 2180 W (2.92 hp) at 65 000 rpm at a pressure drop across the seal of 1.21 MPa (175 psid).

Staging effects are significant. In LN_2, two brushes far apart (spaced 7.21 mm or 0.284 in.) leaked less than two brushes tightly packed. In the three-brushes-evenly-spaced configuration, the pressure load was not always split evenly between the seals. The split of the pressure load seemed to depend on the shaft speed. Further testing is needed to fully understand staging effects.

After accumulating 4.31 hr of rotordynamically stable shaft rotation time in liquid nitrogen, the Inconel 718 shaft had a maximum groove depth of 25 μm (0.001 in.), and the Haynes-25 bristles had worn 25 to 76 μm (0.001 to 0.003 in.). However, in LH_2 the bristle wear was substantially worse, consuming the entire initial radial interference of 127 μm (0.005 in.) after accumulating 1.8 hr of shaft rotation time. It is important to recognize that the time at which the bristle wear occurred during this 1.8 hr is unknown. The greater wear in LH_2 may be attributed to the higher shaft speeds, an effect of the hydrogen environment, or both. Because bristle material transferred onto the runner and there was no wear of the runner in liquid hydrogen, it is possible that the higher shaft speeds used in the LH_2 testing raised the bristle temperature enough to substantially reduce its shear strength, allowing the bristle material to smear. It is also possible that hydrogen, a reducing agent, acts as a catalyst to weld the similar materials within the brush and rotor materials. Further testing is needed to fully understand the wear mechanisms and to investigate several runner coatings that may alleviate the wear problem in LH_2. Additional leakage performance data are also needed to calibrate and validate analytical models of brush seals for cryogenic applications.

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio, April 10, 1996

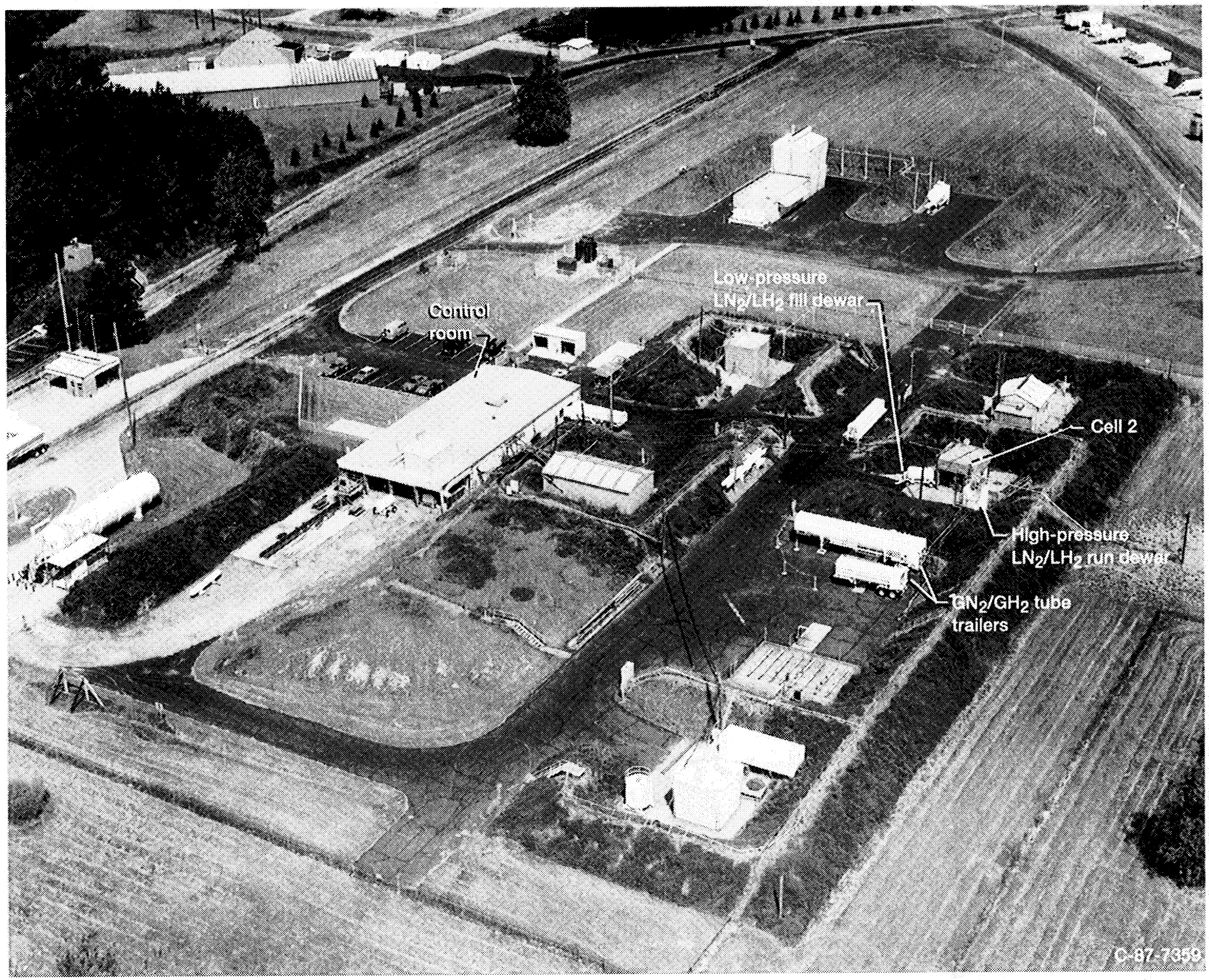


Figure 1.—Cryogenics Components Laboratory (CCL) at the NASA Lewis Research Center.

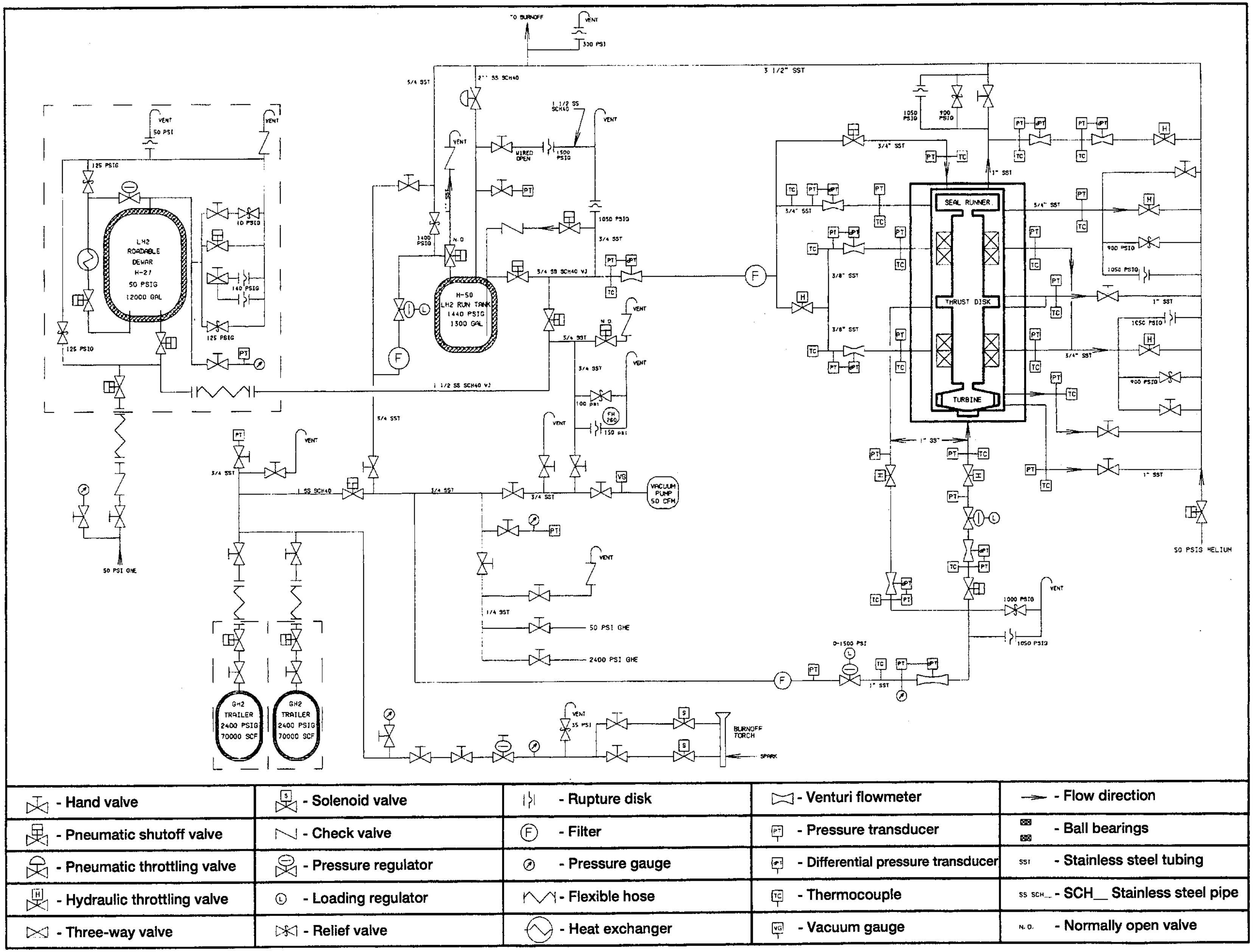


Figure 2.—Brush seal liquid hydrogen (LH_2) test piping. (All pressures are in psig unless noted.)

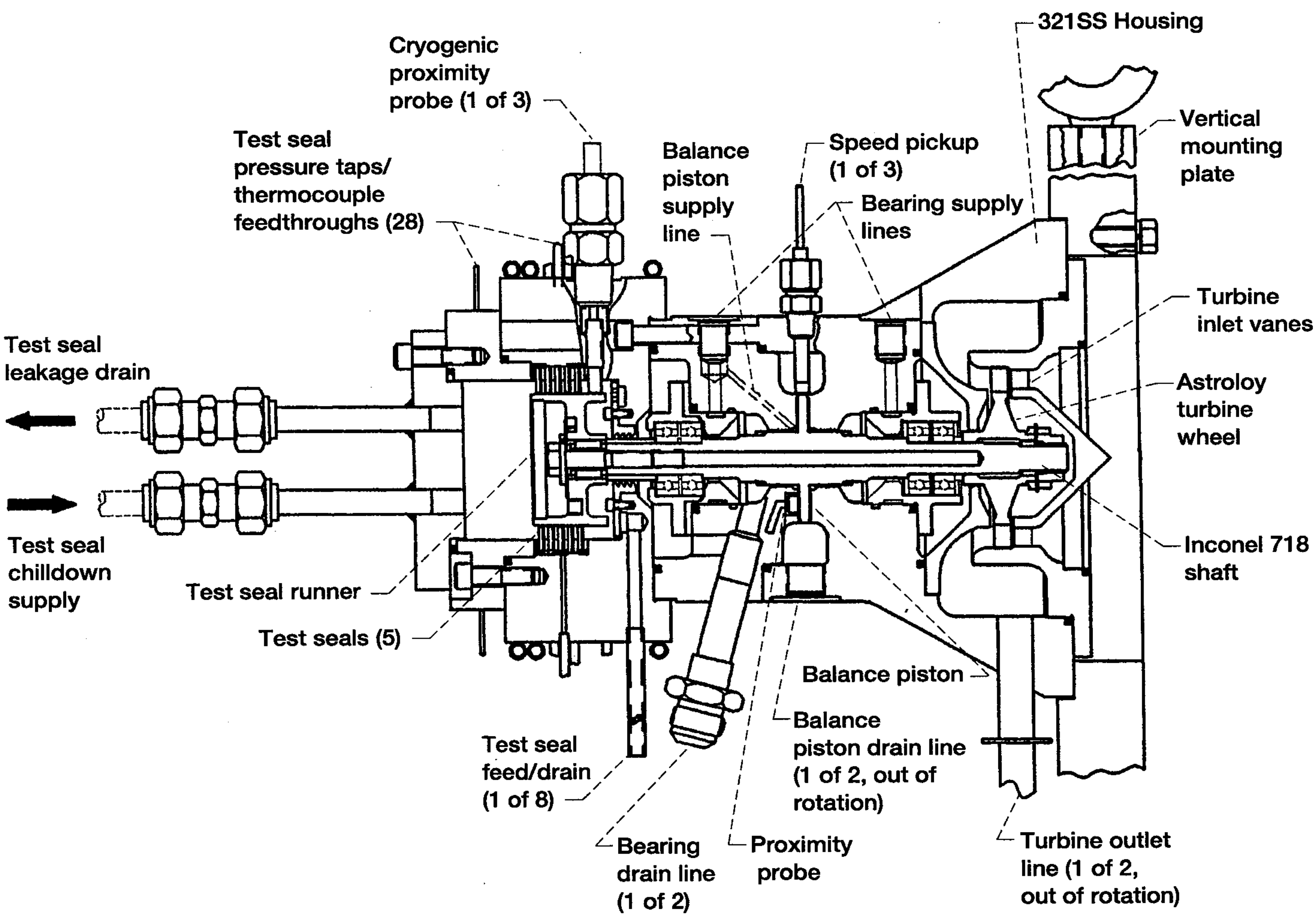


Figure 3.—Cross section of Cryogenic Brush Seal Tester. (Some parts shown out of rotation for clarity.)

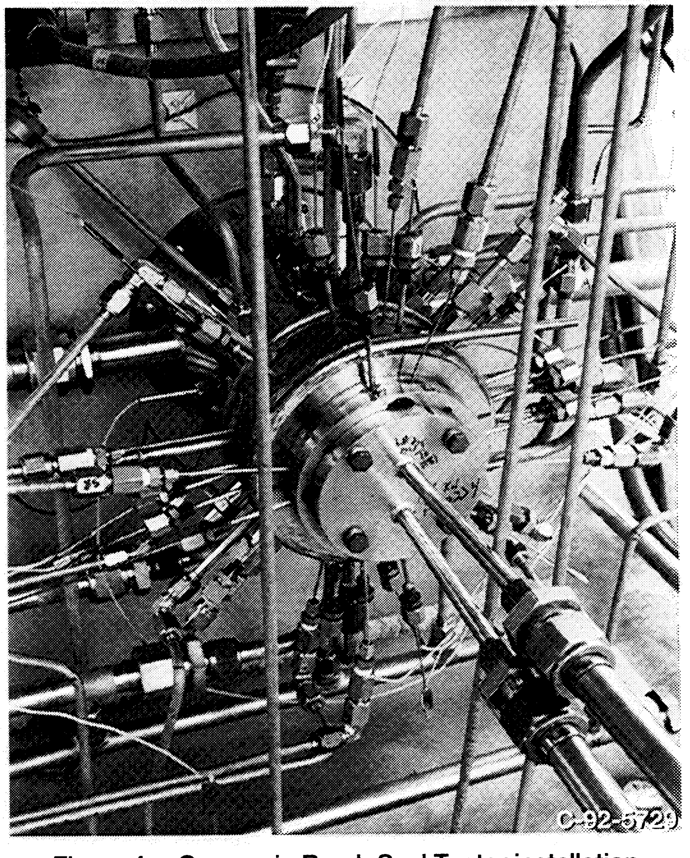


Figure 4.—Cryogenic Brush Seal Tester installation.

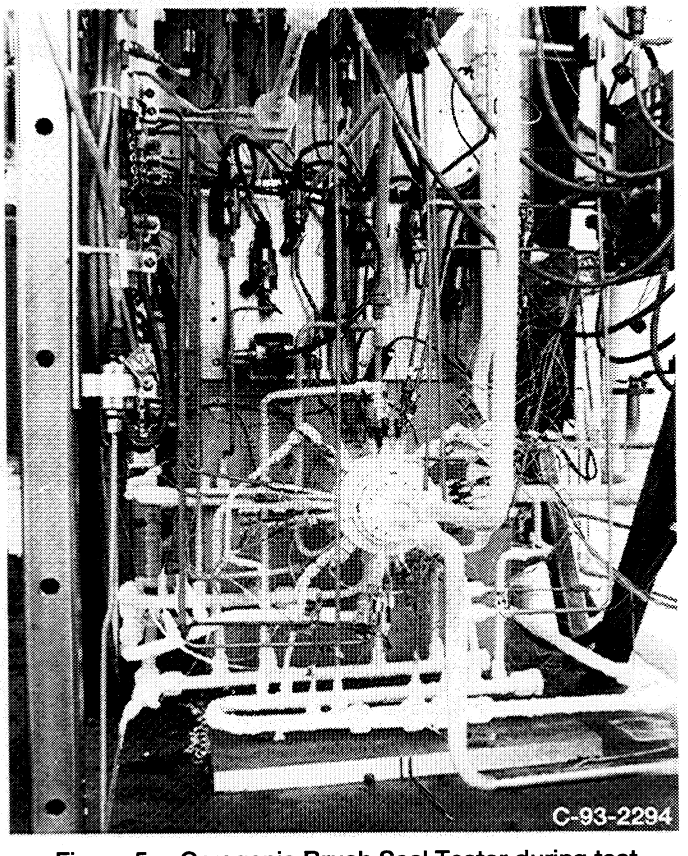


Figure 5.—Cryogenic Brush Seal Tester during test.

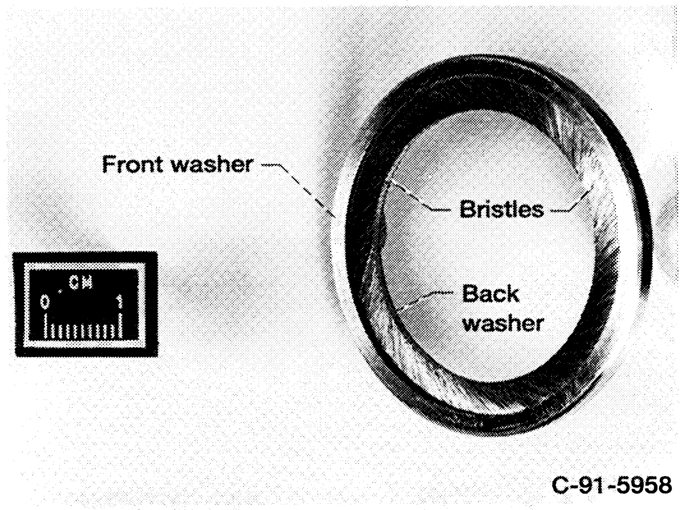
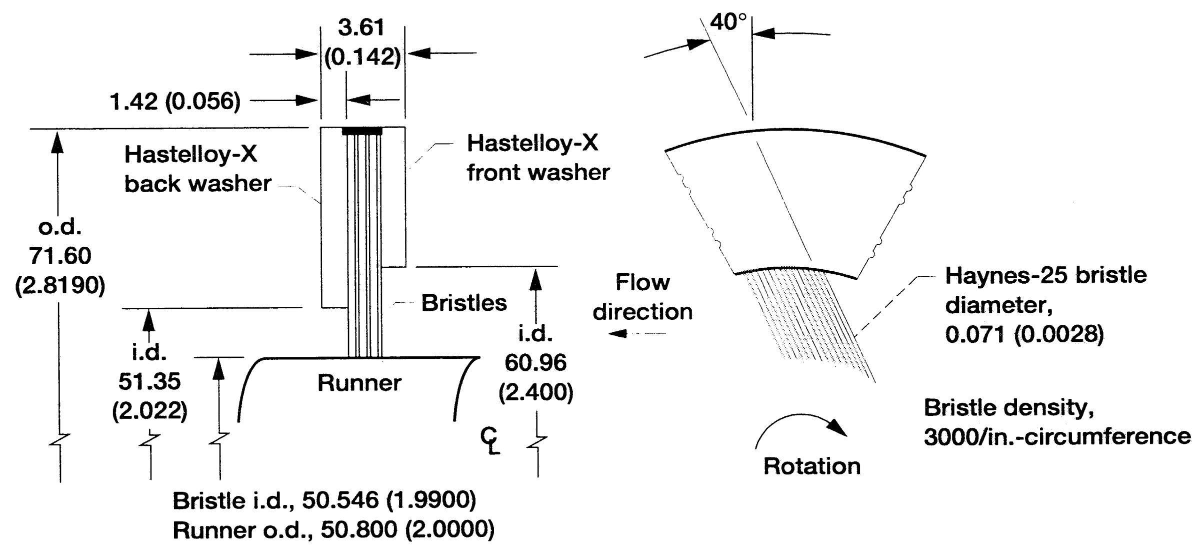


Figure 6.—Typical brush seal.



Runner axial length	
Low speed	28.44 (1.120)
High speed	15.27 (0.601)
Radial interference	.127 (0.005)
Radial clearance between back washer and runner	.279 (0.011)
Radial distance between—	
Back washer and bristle inside diameter	.406 (0.016)
Front washer and bristle inside diameter	5.207 (0.205)

Figure 7.—Nominal brush seal and runner geometry. (Not to scale; all dimensions are in mm (in.).)

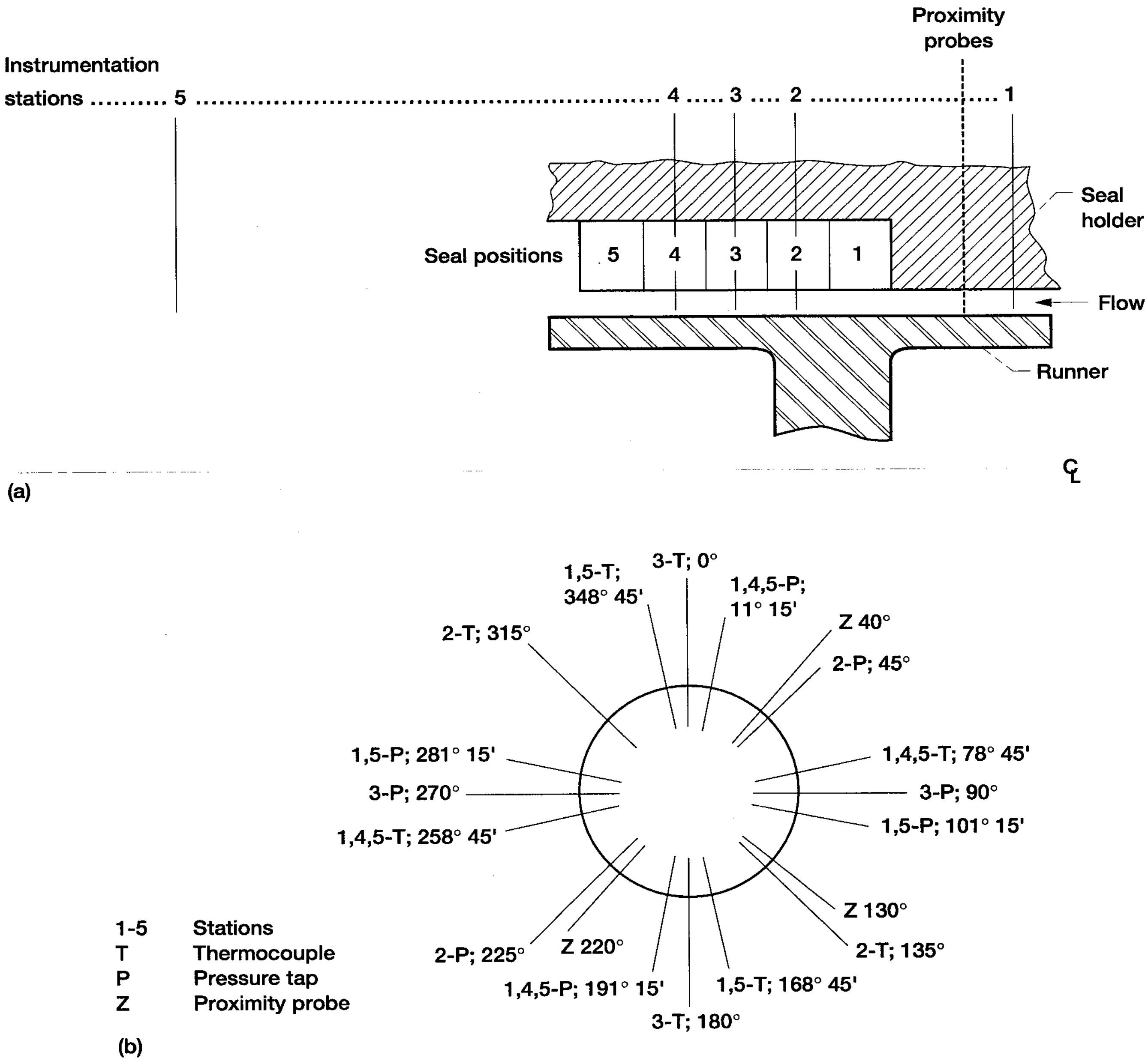


Figure 8.—Location of brush seal positions and instrumentation stations. Low-speed runner shown. (a) Axial locations. (b) Circumferential locations. View looking from seal end.

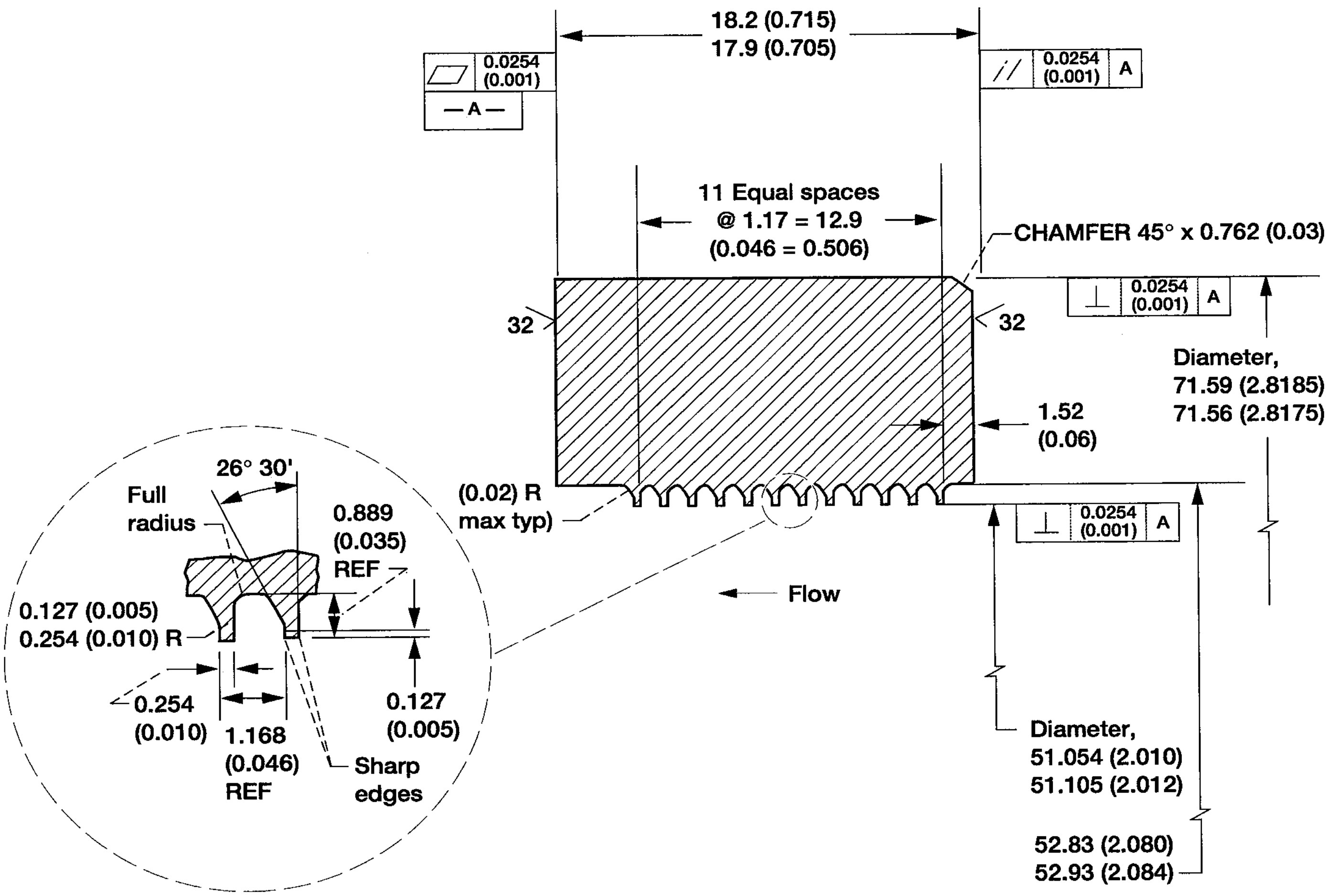


Figure 9.—Labyrinth seal geometry; material, Inconel 718. Dimensions in mm (in.).

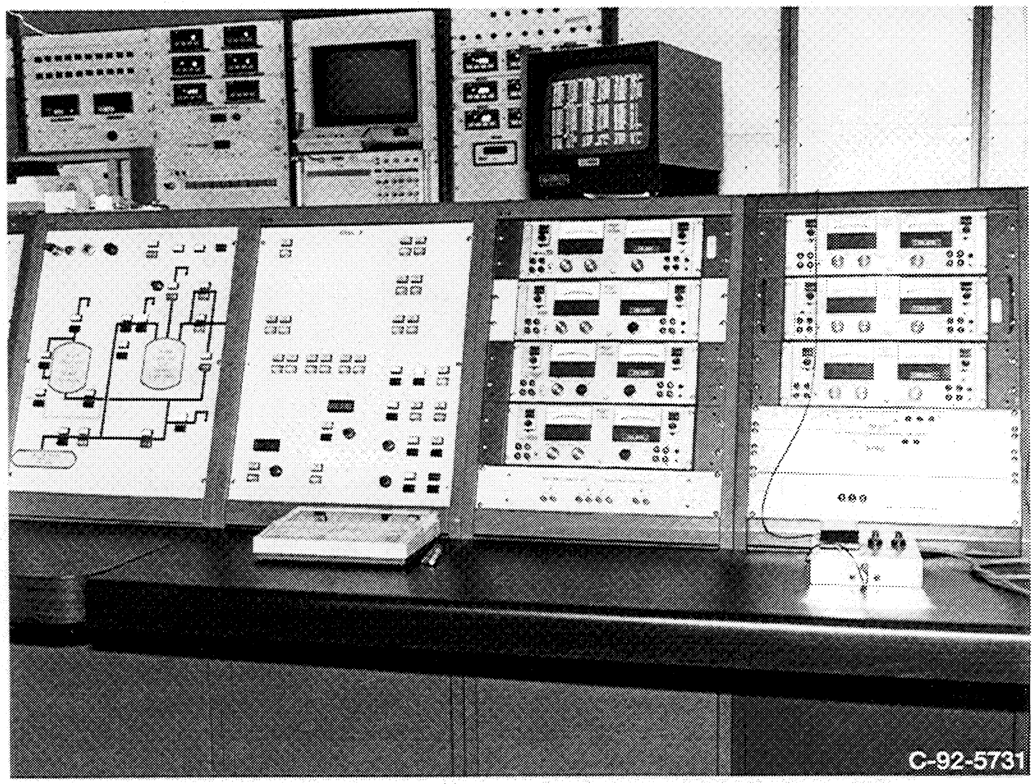


Figure 10.—Control panel for cryogenic brush seal testing.

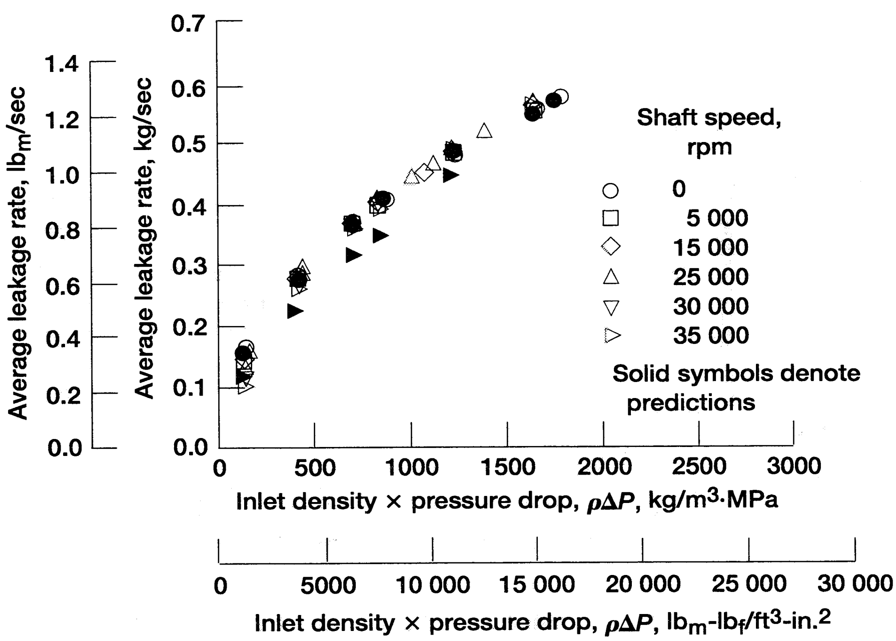


Figure 11.—Comparison of predicted and measured average LN_2 leakage rate through 12-tooth labyrinth seal as function of inlet density times pressure drop across seal for configuration 1 at several shaft speeds. Seal radial clearance, 127-μm (0.005-in.); seal runner outside diameter, 50.794 mm (1.9998 in.).

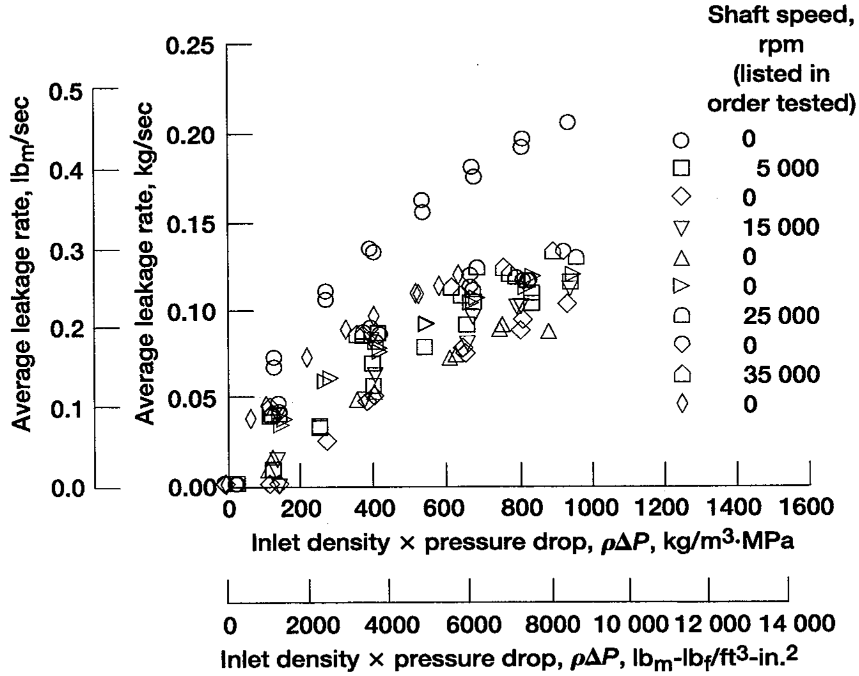


Figure 12.—Average LN_2 leakage rate for single brush seal with initial radial interference of 0.102 mm (0.004 in.) as function of inlet density times pressure drop across seal for configuration 2 at all speeds tested.

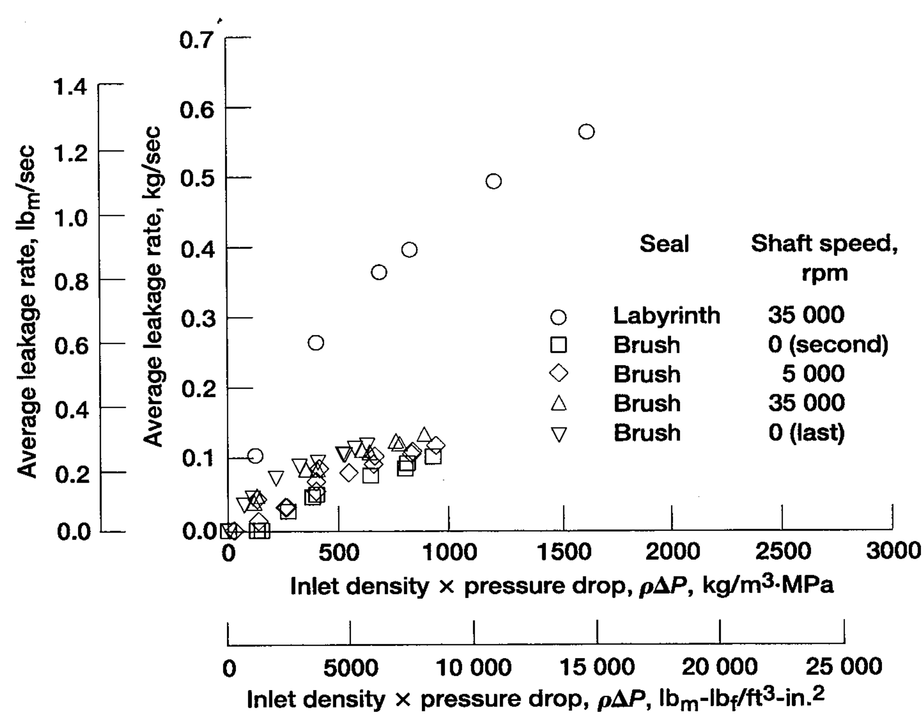


Figure 13.—Comparison of 12-tooth labyrinth seal and single brush seal LN_2 leakage performance. Labyrinth seal radial clearance, 0.127-μm (0.005-in.); brush seal initial radial interference, 0.102 mm (0.004 in.).

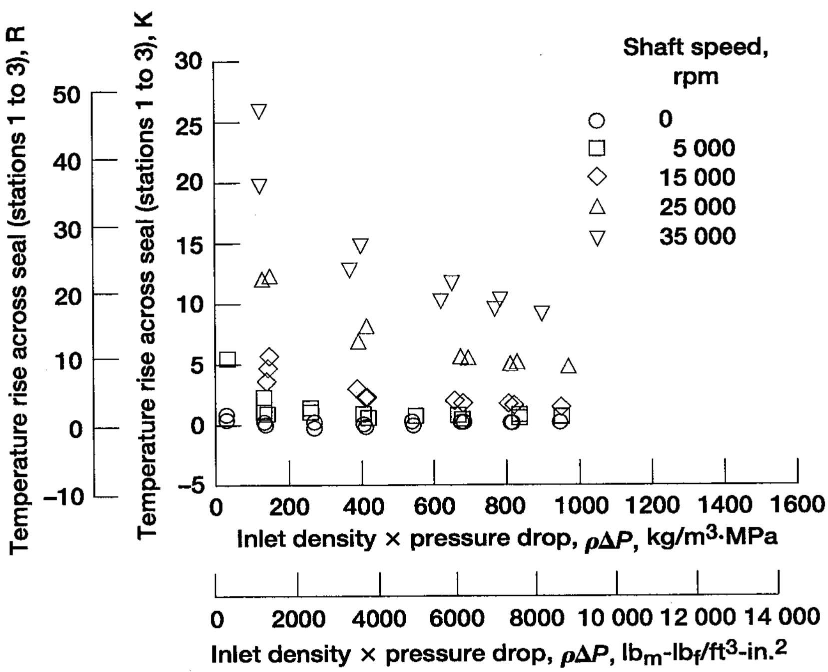


Figure 14.—Effect of speed on LN_2 temperature rise across single brush seal (stations 1 to 3) as function of inlet density times pressure drop across seal for configuration 2.

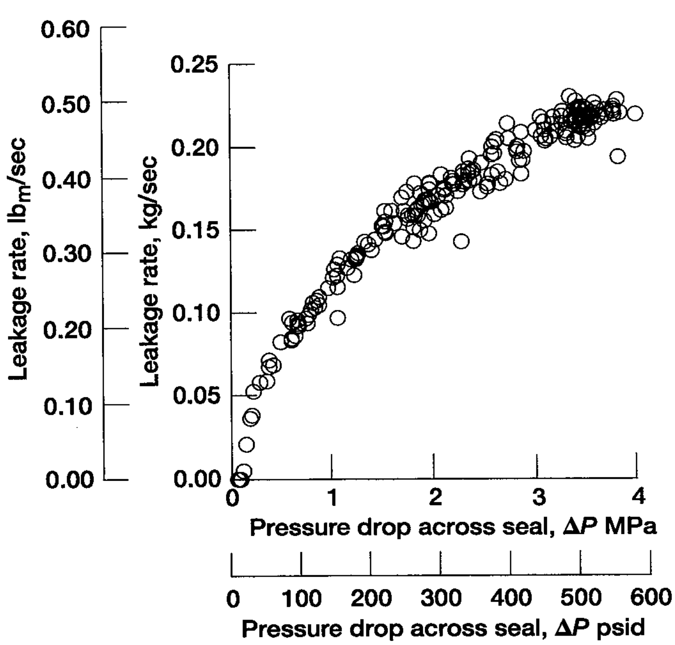


Figure 15.—LN_2 leakage rate as function of pressure drop across single brush seal during static performance test for configuration 8 at 0 rpm.

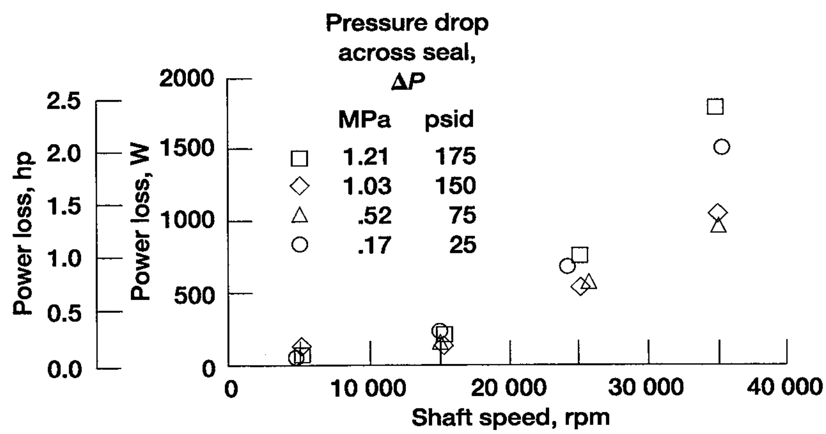


Figure 16.—Power loss to fluid across single brush seal in LN_2 as function of shaft speed for configuration 2.

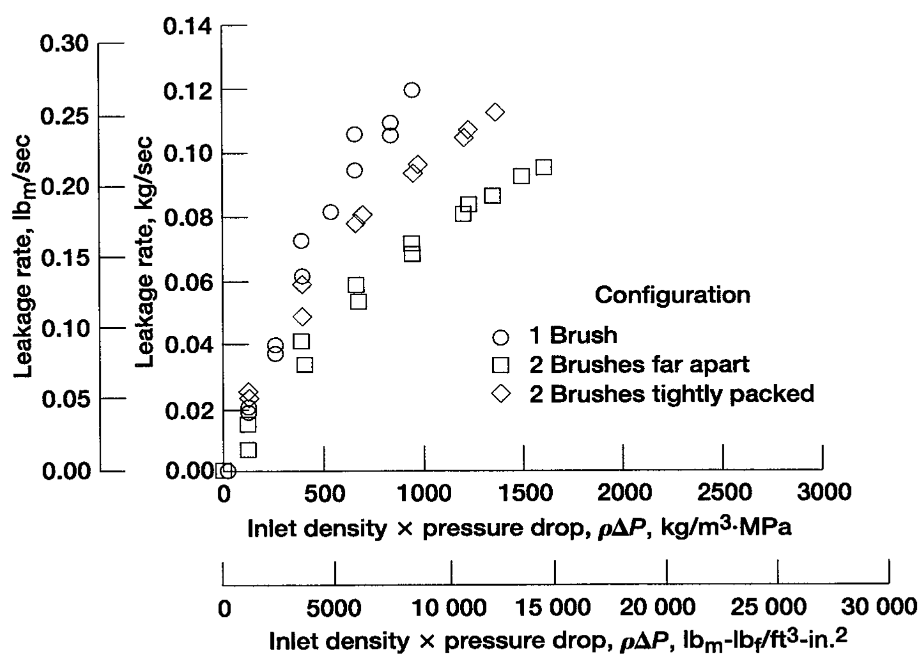


Figure 17.—Comparison of LN_2 leakage rate of one- and two-brush seals in configurations 2 to 4 at 5000 rpm.

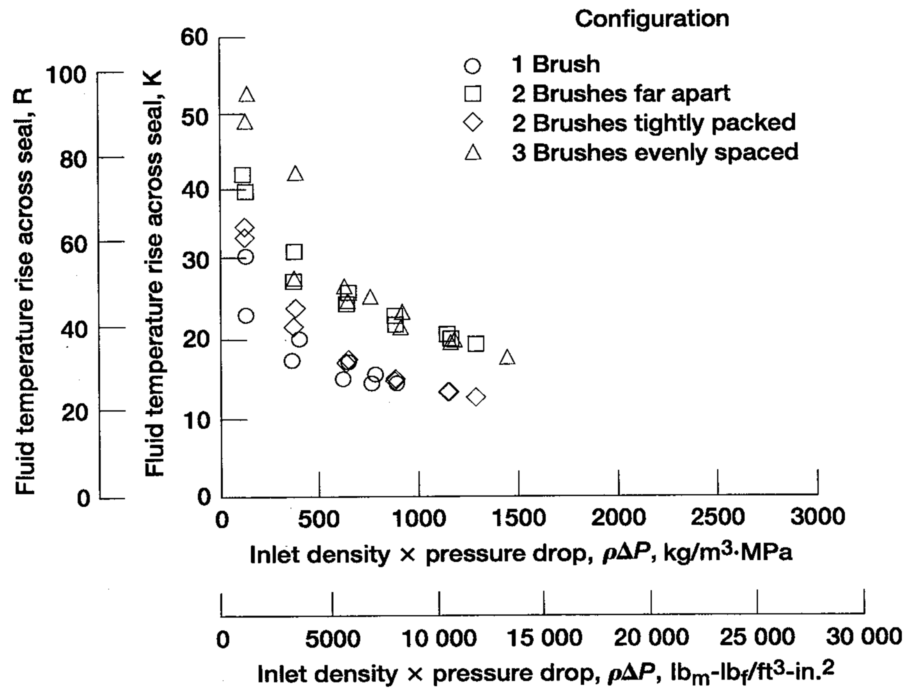


Figure 18.—Effects of staging on fluid temperature rise across seal in LN_2 for configurations 2 to 5 at 35 000 rpm.

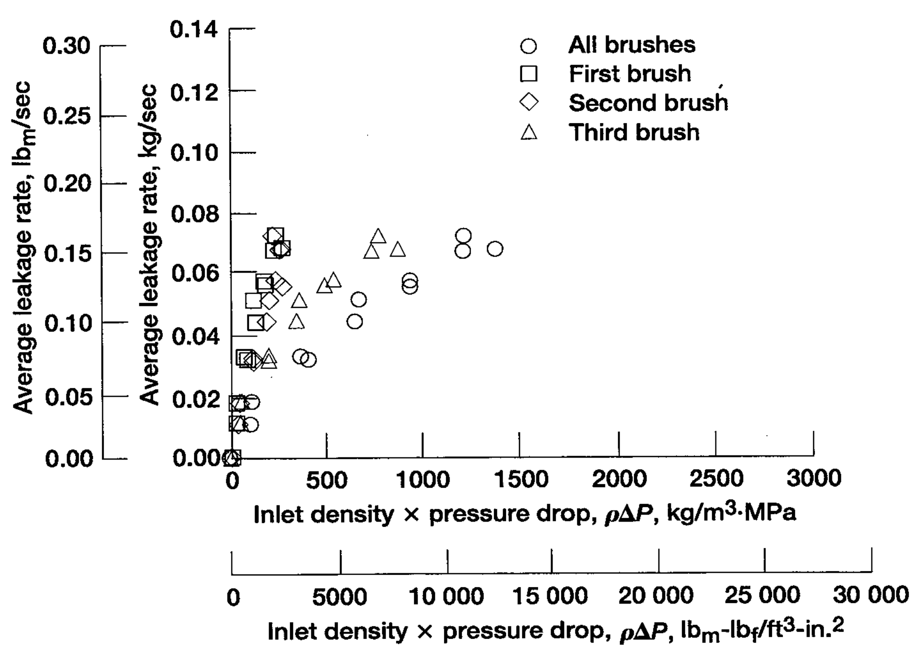


Figure 19.—LN_2 leakage performance of each stage and of all stages for three brushes evenly spaced (configuration 7) at 0 rpm.

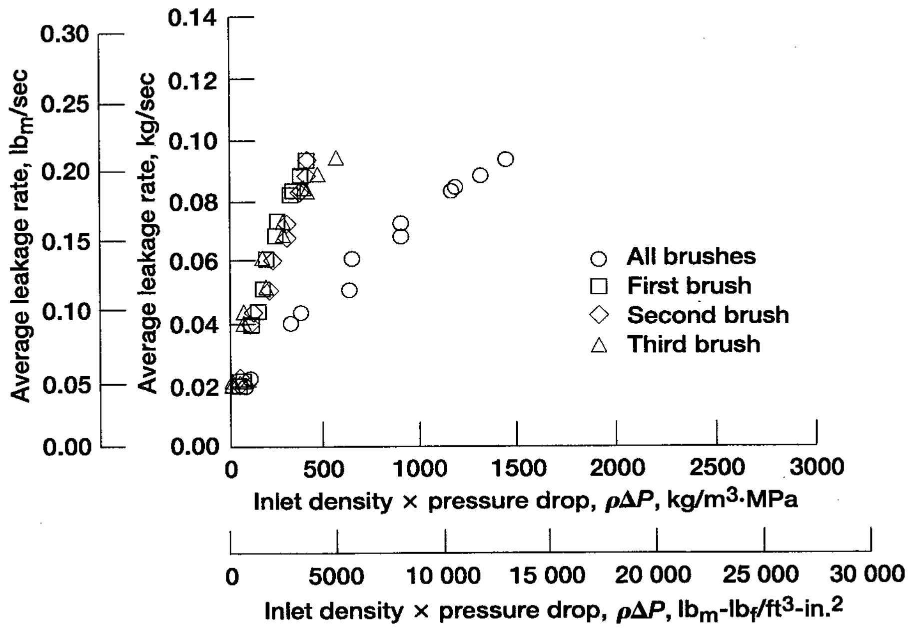
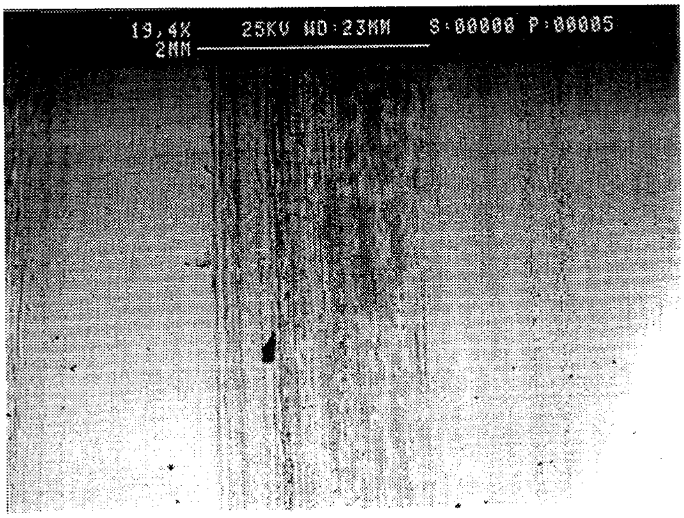
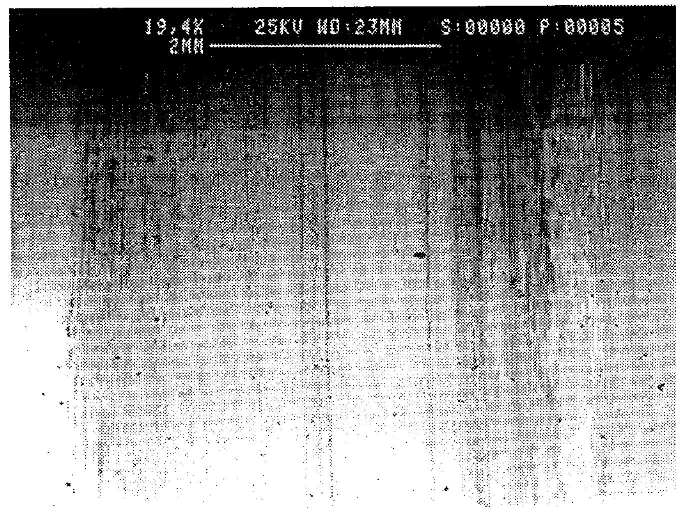


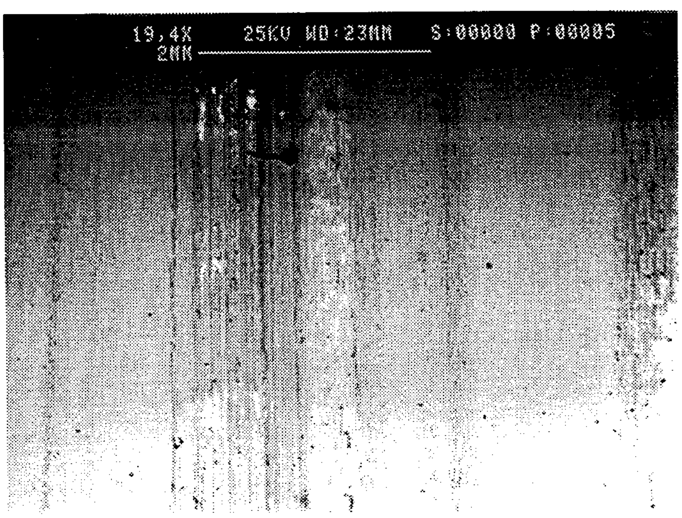
Figure 20.—LN_2 leakage performance of each stage and of all stages for three brushes evenly spaced (configuration 7) at 35 000 rpm.



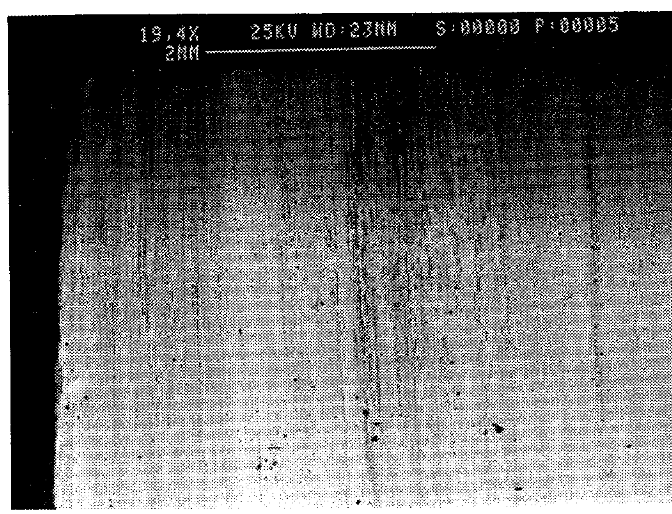
Track 1



Track 3 Track 2



Track 4



Track 5

Figure 21.—Scanning electron microscope (SEM) photographs of wear tracks in low-speed runner after testing configurations 1 to 7.

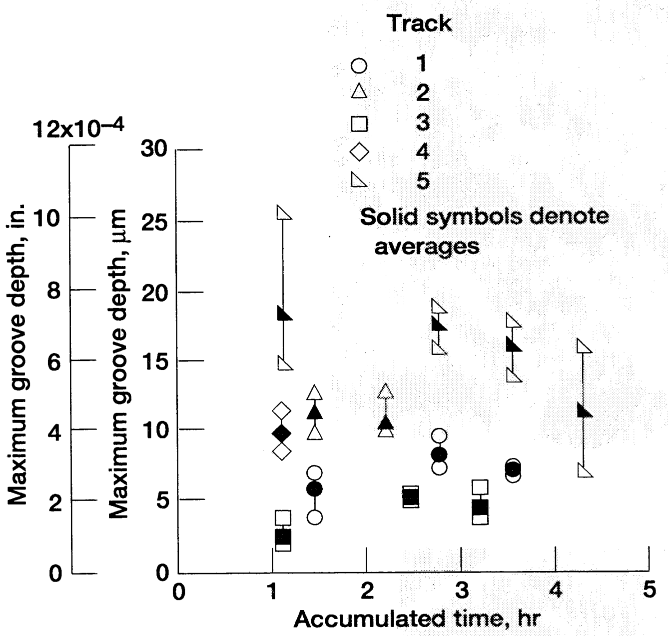


Figure 24.—Maximum, minimum, and average groove depth of brush seal wear tracks on low-speed runner after testing configurations 1 to 8 in LN_2 as function of accumulated time of shaft rotation.

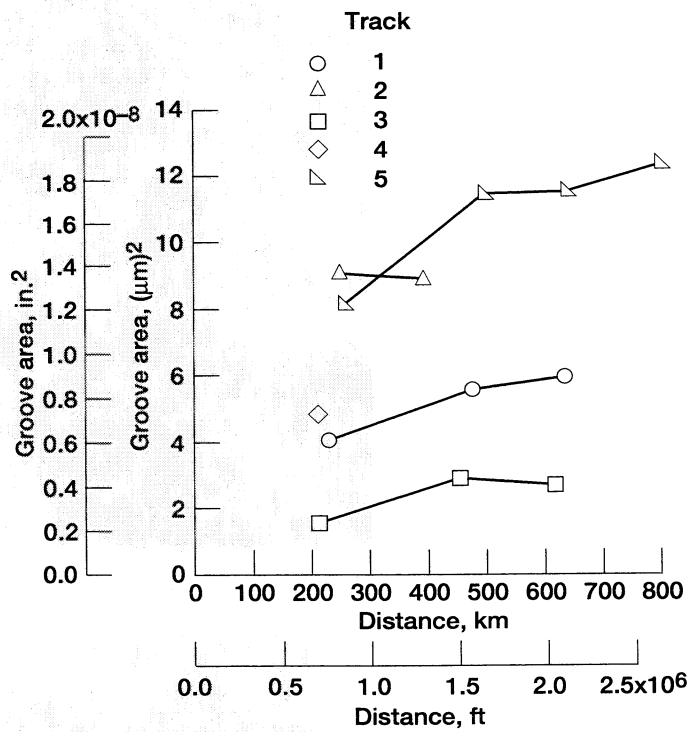


Figure 25.—Average groove area of brush seal wear tracks after testing configurations 1 to 8 in LN_2 as function of rotation distance.

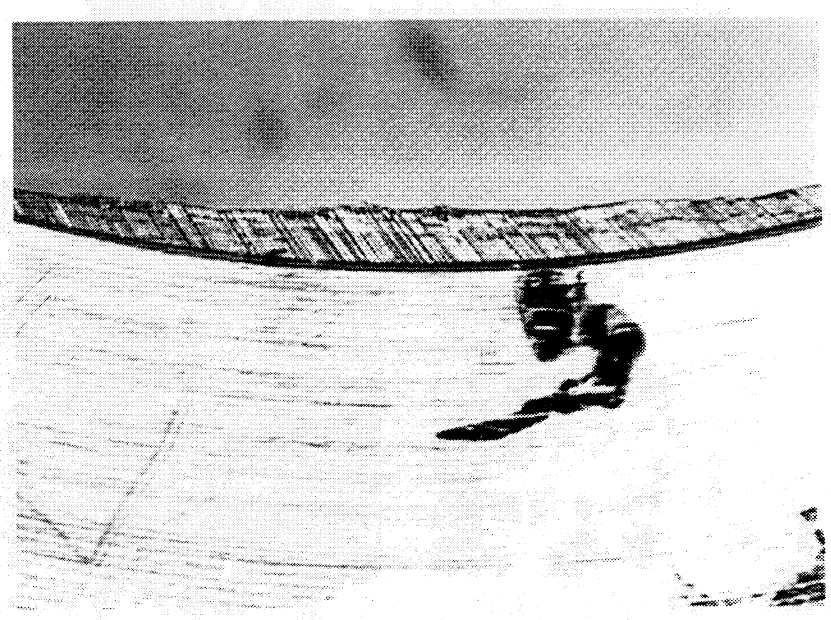


Figure 26.—Posttest brush seal showing unevenness of bristles.

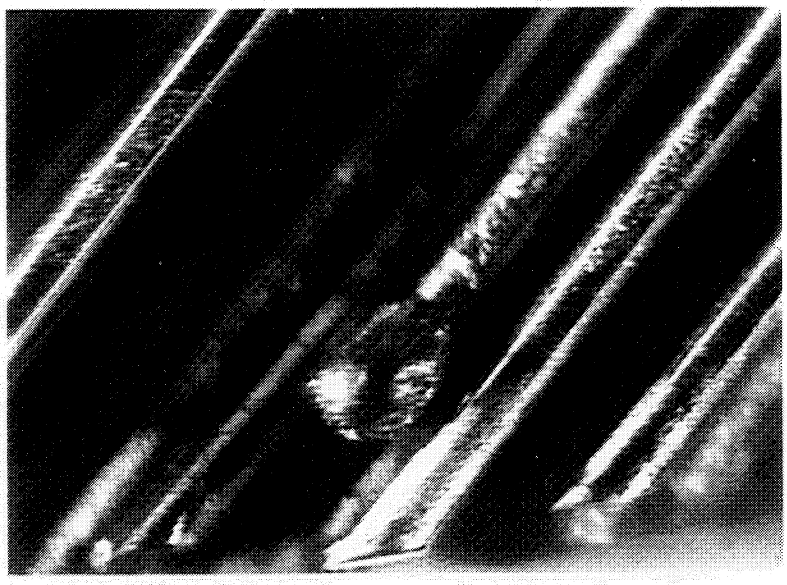
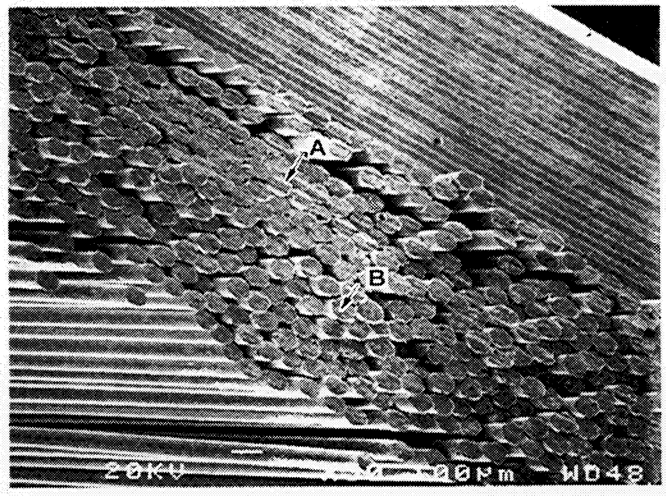
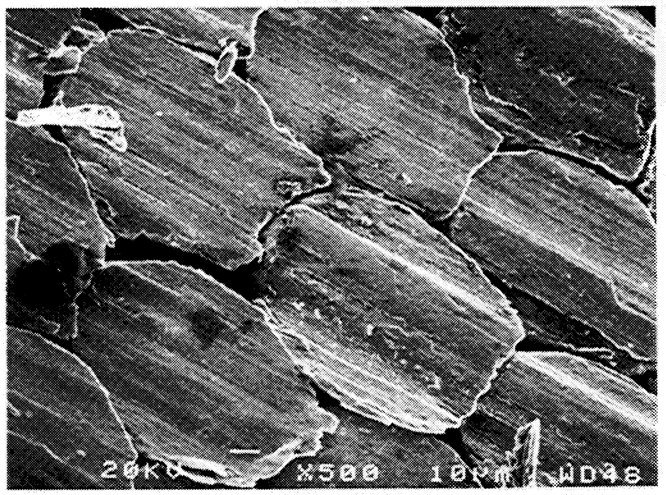
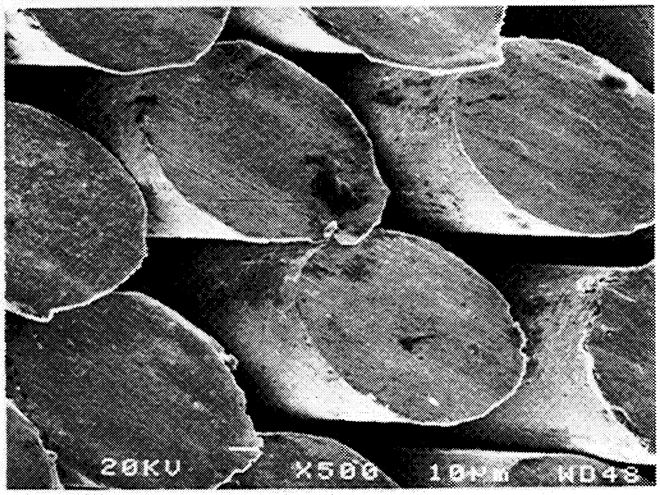


Figure 27.—Melted bristle tip.





Region A



Region B

Figure 28.—Bristle wear in LN_2 tests; substantial wear shown on downstream bristles (region A) which were closer to back washer.

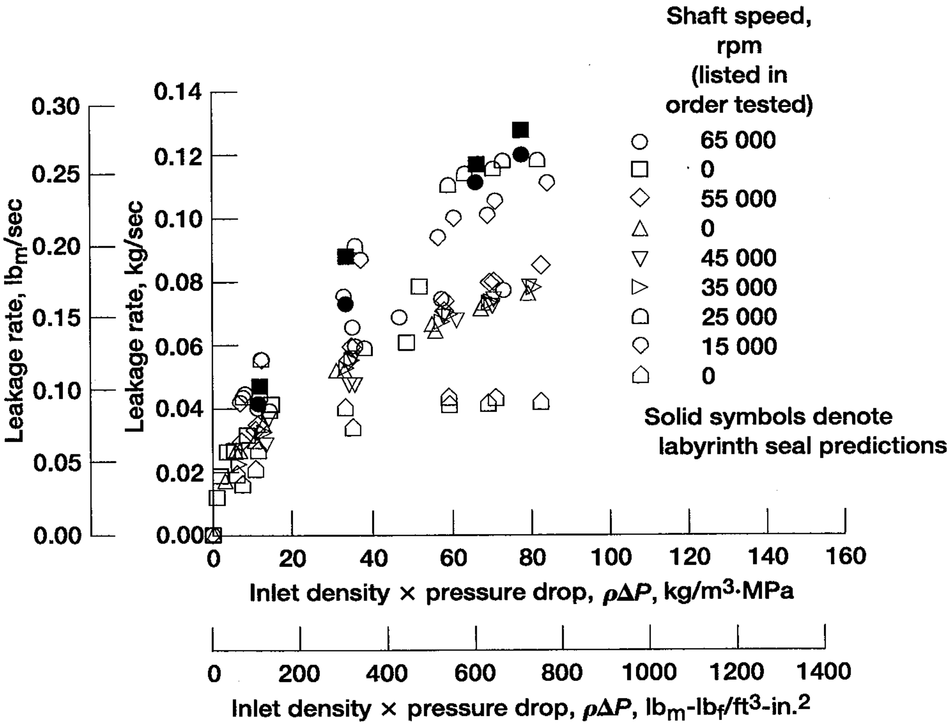


Figure 29.—Comparison of LH_2 leakage performance of single brush seal at various speeds and leakage predictions for 12-tooth, 0.127-μm- (0.005-in.-) radial-clearance labyrinth seal at 0 and 65 000 rpm as function of inlet density times pressure drop across seal for configuration 9.

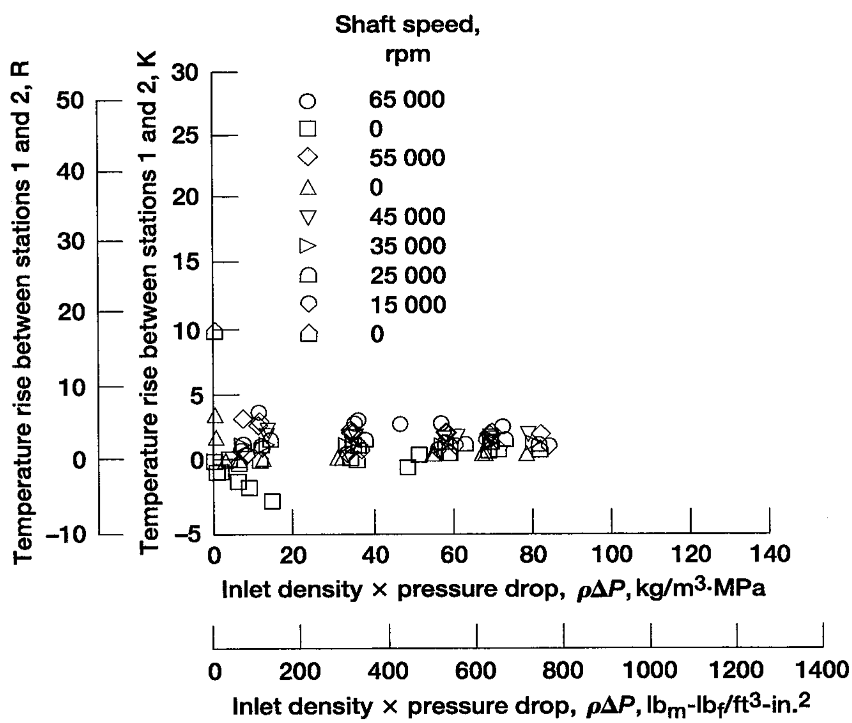


Figure 30.—Temperature rise across single brush seal in LH_2 as function of inlet density times pressure drop across seal for configuration 9 at all shaft speeds.

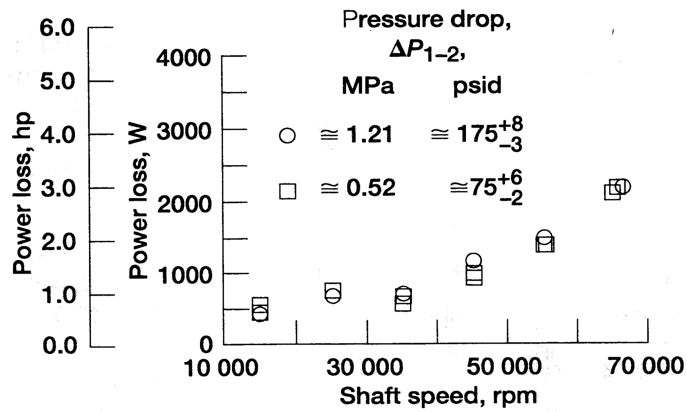


Figure 31.—Power loss to fluid across brush seal in LH_2 as function of shaft speed for pressure drops across seal of 0.52 and 1.21 MPa (75 and 175 psid). Power loss is $\dot{m}\,(h_2 - h_1)$ in watts (hp = $(778/550)\dot{m}(h_2 - h_1)$) where $\dot{m}$ is mass flow rate through seal, kg/sec (lb_m/sec); and h_2 and h_1 are the fluid enthalpy at stations 1 and 2, J/kg (Btu/lb).

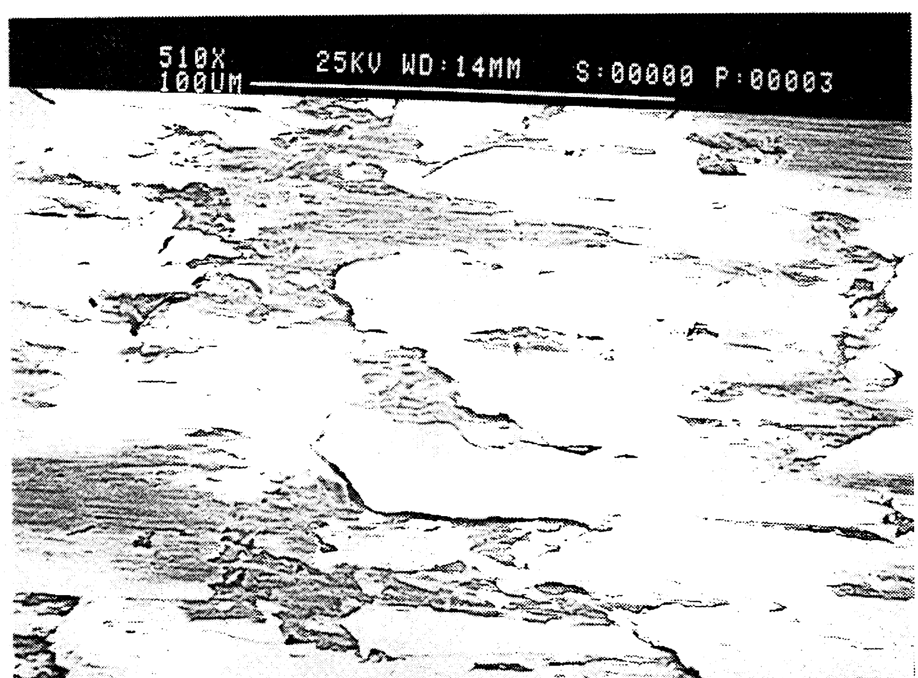


Figure 32.—Bristle material transferred to seal runner after testing in LH_2. Configuration 9. Magnification 510.

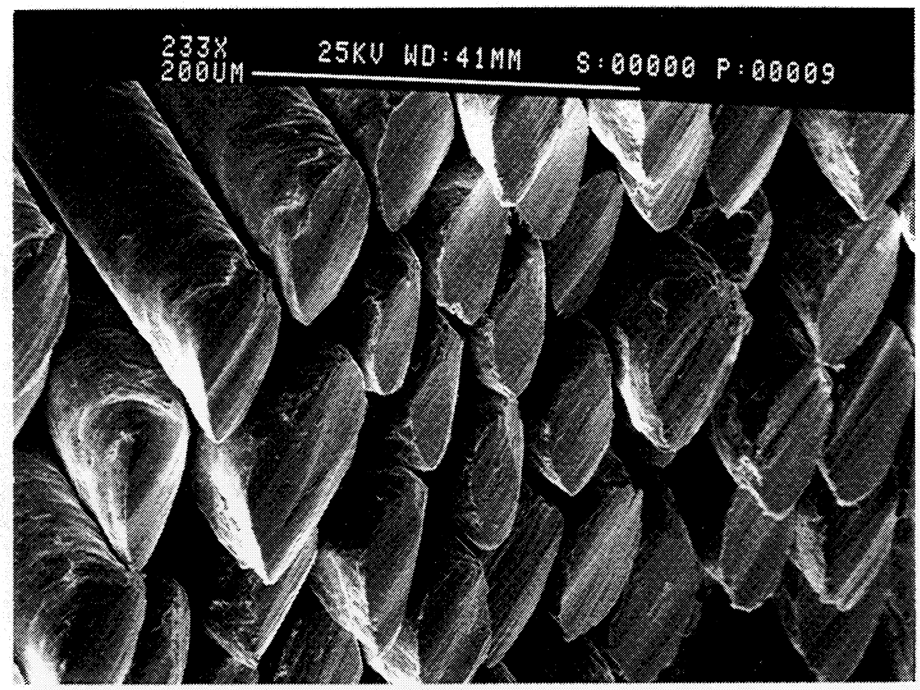


Figure 33.—Smearing type wear of Haynes-25 bristle tips after testing in LH_2. Configuration 9. Magnification 233.

Figure 34.—Outer bristles of brush seal bent axially after testing in LH_2. Configuration 9.

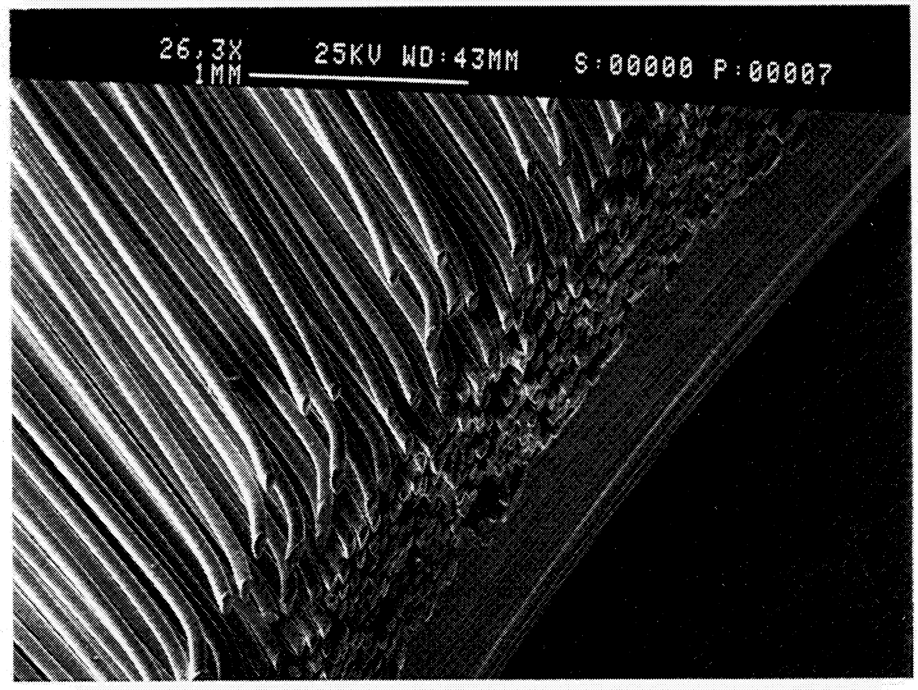


Figure 35.—Outer bristles of brush seal exhibiting tip bending in circumferential direction after testing in LH_2. Configuration 9.

Appendix A

Instrument Description List

Escor Chan. No.	FM-tape Chan. No.	Name	Expected Engineering Units Range	Location/Description
1		GHSPLY	0-3000 PSIG	GH2 SUPPLY PRESSURE FROM TUBE TRAILER AT CELL
2		GHIN	0-3000 PSIG	GH2 PRESSURE UPSTREAM OF MAIN SUPPLY REGULATOR FH269 IN CELL
3		GHMNVN	0-2000 PSIG	GH2 MAIN SUPPLY LINE VENTURI PRESSURE
4		GHMVDP	0-50 PSID	GH2 MAIN SUPPLY LINE VENTURI DELTA P
5		GHTBVN	0-2000 PSIG	GH2 TURBINE SUPPLY LINE VENTURI PRESSURE
6		GHTVDP	0-100 PSID	GH2 TURBINE SUPPLY LINE DELTA P
7		GHRGPR	0-2000 PSIG	GH2 TURBINE SUPPLY LINE REGULATOR OUTLET PRESSURE
8		GHTBIN	0-2000 PSIG	GH2 TURBINE INLET PRESSURE AT RIG
9		GHBTVN	0-2000 PSIG	GH2 BALANCE PISTON TURBINE SIDE VENTURI PRESSURE
10		GHBTDP	0-50 PSID	GH2 BALANCE PISTON TURBINE SIDE VENTURI DELTA P
11		GHBTIN	0-2000 PSIG	GH2 BALANCE PISTON TURBINE SIDE INLET PRESSURE AT RIG
12		GHBSVN	0-2000 PSIG	GH2 BALANCE PISTON SEAL SIDE VENTURI PRESSURE
13		GHBSDP	0-10 PSID	GH2 BALANCE PISTON SEAL SIDE VENTURI DELTA P
14		GHBSIN	0-2000 PSIG	GH2 BALANCE PISTON SEAL SIDE INLET PRESSURE AT RIG
15		GHTNIN	0-1000 PSIG	GH2 TURBINE NOZZLE INLET PRESSURE
16		GHTNOC	0-1000 PSIG	GH2 TURBINE NOZZLE OUTLET CAVITY PRESSURE
17		GHROUT	0-1000 PSIG	GH2 TURBINE ROTOR OUTLET CAVITY PRESSURE
18		GHTOTP	0-1000 PSIG	GH2 TURBINE OUTLET TORUS PRESSURE
19		GHTNOT	0-1000 PSIG	GH2 TURBINE NOZZLE OUTLET TIP PRESSURE
20		GHTNOH	0-1000 PSIG	GH2 TURBINE NOZZLE OUTLET HUB PRESSURE
21		GHROT	0-1000 PSIG	GH2 TURBINE ROTOR OUTLET TIP PRESSURE
22		GHROH	0-1000 PSIG	GH2 TURBINE ROTOR OUTLET HUB PRESSURE
23		GHTO1	0-1000 PSIG	GH2 TURBINE OUTLET LINE PRESSURE 1
24		GHTO2	0-1000 PSIG	GH2 TURBINE OUTLET LINE PRESSURE 2
25		GHBPO	0-2000 PSIG	GH2 BALBANCE PISTON OUTLET LINE PRESSURE
26		PRTANK	0-3000 PSIG	LH2 TANK H-50 PRESSURE
27		LHMNVN	0-2000 PSIG	LH2 MAIN SUPPLY LINE VENTURI PRESSURE
28		LHMVDP	0-300 PSID	LH2 MAIN SUPPLY LINE VENTURI DELTA P
29		LHTBVN	0-2000 PSIG	LH2 TURBINE SIDE BEARING SUPPLY LINE VENTURI PRESSURE
30		LHTBDP	0-100 PSID	LH2 TURBINE SIDE BEARING SUPPLY LINE VENTURI DELTA P
31		LHSBVN	0-2000 PSIG	LH2 SEAL SIDE BEARING SUPPLY LINE VENTURI PRESSURE
32		LHSBDP	0-50 PSID	LH2 SEAL SIDE BEARING SUPPLY LINE VENTURI DELTA P
33		LHSIVN	0-2000 PSIG	LH2 BRUSH SEAL INLET LINE VENTURI PRESSURE
34		LHSIDP	0-100 PSID	LH2 BRUSH SEAL INLET LINE VENTURI DELTA P
35		LHTBI	0-2000 PSIG	LH2 TURBINE SIDE BEARING SUPPLY LINE INLET PRESSURE AT RIG
36		LHSBI	0-2000 PSIG	LH2 SEAL SIDE BEARING SUPPLY LINE INLET PRESSURE AT RIG
37		LHSI	0-2000 PSIG	LH2 BRUSH SEAL INLET LINE PRESSURE AT RIG
38		LHSBYI	0-2000 PSIG	LH2 BRUSH SEAL CHILL DOWN BYPASS LINE INLET PRESSURE
39				
40		LHTBO	0-1000 PSIG	LH2 TURBINE SIDE BEARING OUTLET LINE PRESSURE
41		LHSBO	0-2000 PSIG	LH2 SEAL SIDE BEARING OUTLET LINE PRESSURE
42		LHSO	0-2000 PSIG	LH2 BRUSH SEAL OUTLET LINE PRESSURE
43		LHSLV1	0-2000 PSIG	LH2 BRUSH SEAL LEAKAGE OUTLET LINE VENTURI PRESSURE 1
44		LHSDP1	0-10 PSID	LH2 BRUSH SEAL LEAKAGE OUTLET LINE VENTURI DELTA P 1
45		LHSLV2	0-2000 PSIG	LH2 BRUSH SEAL LEAKAGE OUTLET LINE VENTURI PRESSURE 2
46		LHSDP2	0-5 PSID	LH2 BRUSH SEAL LEAKAGE OUTLET LINE VENTURI DELTA P 2
47				
48		GHTOTT	360-600 R	GH2 TURBINE OUTLET TORUS TOEMPERATURE
49		GHBPOT	100-600 R	GH2 BALANCE PISTON OUTLET LINE TEMPERATURE
50		GHMVT	360-600 R	GH2 MAIN SUPPLY LINE VENTURI TEMPERATURE
51		GHTVT	360-600 R	GH2 TURBINE SUPPLY LINE VENTURI TEMPERATURE
52		GHTIT	360-600 R	GH2 TURBINE SUPPLY LINE INLET TEMPERATURE AT RIG
53		GHBTVT	360-600 R	GH2 BALANCE PISTON TURBINE SIDE VENTURI TEMPERATURE
54		GHBSVT	360-600 R	GH2 BALANCE PISTON SEAL SIDE VENTURI TEMPERATURE

Escor Chan. No.	FM-tape Chan. No.	Name	Expected Engineering Units Range	Location/Description
55		GHTOT1	100-600 R	GH2 TURBINE OUTLET LINE TEMPERATURE 1
56		GHTOT2	100-600 R	GH2 TURBINE OUTLET LINE TEMPERATURE 2
57		LHMVT	36-600 R	LH2 MAIN SUPPLY LINE VENTURI TEMPERATURE
58		LHTBVT	36-600 R	LH2 TURBINE SIDE BEARING SUPPLY LINE VENTURI TEMPERATURE
59		LHSBVT	36-600 R	LH2 SEAL SIDE BEARING SUPPLY LINE VENTURI TEMPERATURE
60		LHSIVT	36-600 R	LH2 BRUSH SEAL INLET LINE VENTURI TEMPERATURE
61		LHTBIT	36-600 R	LH2 TURBINE SIDE BEARING SUPPLY LINE INLET TEMPERATURE AT RIG
62		LHSBIT	36-600 R	LH2 SEAL SIDE BEARING SUPPLY LINE INLET TEMPERATURE AT RIG
63		LHSIT	36-600 R	LH2 BRUSH SEAL INLET LINE TEMPERATURE AT RIG
64		LHSBYT	36-600 R	LH2 BRUSH SEAL CHILLDOWN LINE INLET TEMPERATURE AT RIG
65				
66		LHTBOT	36-600 R	LH2 TURBINE SIDE BEARING OUTLET LINE TEMPERATURE AT RIG (REDUNDANT THERMOCOUPLE USED FOR ABORT)
67		LHSBOT	36-600 R	LH2 SEAL SIDE BEARING OUTLET LINE TEMPERATURE AT RIG (REDUNDANT THERMOCOUPLE USED FOR ABORT)
68		LHSOT	36-600 R	LH2 BRUSH SEAL OUTLET LINE TEMPERATURE AT RIG
69		LHSLT1	36-700 R	LH2 BRUSH SEAL LEAKAGE OUTLET LINE VENTURI TEMPERATURE 1
70		LHSLT2	36-700 R	LH2 BRUSH SEAL LEAKAGE OUTLET LINE VENTURI TEMPERATURE 2
71			36-600 R	SHORTED INPUT TO INDICATE REFERENCE TEMPERATURE
72		PST1A	0-2000 PSIG	PRESSURE AT STATION 1 - 11 DEG., 15 MIN.
73		PST1B	0-2000 PSIG	PRESSURE AT STATION 1 - 101 DEG., 15 MIN.
74		PST1C	0-2000 PSIG	PRESSURE AT STATION 1 - 191 DEG., 15 MIN.
75		PST1D	0-2000 PSIG	PRESSURE AT STATION 1 - 281 DEG., 15 MIN.
76		PST2E	0-2000 PSIG	PRESSURE AT STATION 2 - 45 DEG.
77		PST2F	0-2000 PSIG	PRESSURE AT STATION 2 - 225 DEG.
78		PST3G	0-2000 PSIG	PRESSURE AT STATION 3 - 90 DEG.
79		PST3H	0-2000 PSIG	PRESSURE AT STATION 3 - 270 DEG.
80		PST4A	0-2000 PSIG	PRESSURE AT STATION 4 - 11 DEG., 15 MIN.
81		PST4C	0-2000 PSIG	PRESSURE AT STATION 4 - 191 DEG., 15 MIN.
82		PST5A	0-2000 PSIG	PRESSURE AT STATION 5 - 11 DEG., 15 MIN.
83		PST5B	0-2000 PSIG	PRESSURE AT STATION 5 - 101 DEG., 15 MIN.
84		PST5C	0-2000 PSIG	PRESSURE AT STATION 5 - 191 DEG., 15 MIN.
85		PST5D	0-2000 PSIG	PRESSURE AT STATION 5 - 281 DEG., 15 MIN.
86		TST1A	36-800 R	TEMPERATURE AT STATION 1 - 78 DEG., 45 MIN.
87		TST1B	36-800 R	TEMPERATURE AT STATION 1 - 168 DEG., 45 MIN.
88		TST1C	36-800 R	TEMPERATURE AT STATION 1 - 258 DEG., 45 MIN.
89		TST1D	36-800 R	TEMPERATURE AT STATION 1 - 348 DEG., 45 MIN.
90		TST2E	36-800 R	TEMPERATURE AT STATION 2 - 135 DEG.
91		TST2F	36-800 R	TEMPERATURE AT STATION 2 - 315 DEG.
92		TST3G	36-800 R	TEMPERATURE AT STATION 3 - 0 DEG.
93		TST3H	36-800 R	TEMPERATURE AT STATION 3 - 180 DEG.
94		TST4A	36-800 R	TEMPERATURE AT STATION 4 - 78 DEG., 45 MIN.
95		TST4C	36-800 R	TEMPERATURE AT STATION 4 - 258 DEG., 45 MIN.
96		TST5A	36-800 R	TEMPERATURE AT STATION 5 - 78 DEG., 45 MIN.
97		TST5B	36-800 R	TEMPERATURE AT STATION 5 - 168 DEG., 45 MIN.
98		TST5C	36-800 R	TEMPERATURE AT STATION 5 - 258 DEG., 45 MIN.
99		TST5D	36-800 R	TEMPERATURE AT STATION 5 - 348 DEG., 45 MIN.
100	2	SP1	0-50000 RPM	SPEED PICKUP OFF OF BALANCE PISTON 1
101	3	SP2	0-50000 RPM	SPEED PICKUP OFF OF BALANCE PISTON 2
102		GHMNFL	0-0.3 LB/S	GH2 FLOW THROUGH MAIN SUPPLY LINE VENTURI (CALC.)
103		GHTFL	0-0.1 LB/S	GH2 FLOW THROUGH TURBINE SUPPLY LINE VENTURI(CALC.)
104		GHBTFL	0-0.2 LB/S	GH2 FLOW THROUGH BALANCE PISTON TURBINE SIDE SUPPLY VENTURI(CALC.)
105		GHBSFL	0-0.2 LB/S	GH2 FLOW THROUGH BALANCE PISTON SEAL SIDE SUPPLY LINE VENTURI(CALC.)
106		LHMNFL	0-0.5 LB/S	LH2 FLOW THROUGH MAIN SUPPLY LINE VENTURI(CALC.)

Escor Chan. No.	FM-tape Chan. No.	Name	Expected Engineering Units Range	Location/Description
107		LHTBFL	0-0.025 LB/S	LH2 FLOW THROUGH TURBINE SIDE BEARING SUPPLY LINE VENTURI (CALC.)
108		LHSBFL	0-0.025 LB/S	LH2 FLOW THROUGH SEAL SIDE BEARING SUPPLY LINE VENTURI (CALC.)
109		LHSFL	0-0.45 LB/S	LH2 FLOW THROUGH BRUSH SEAL SUPPLY LINE VENTURI (CALC.)
110		LHSLF1	0-0.2 LB/S	LH2 FLOW THROUGH BRUSH SEAL LEAKAGE LINE VENTURI 1 (CALC.)
111		LHSLF2	0-0.2 LB/S	LH2 FLOW THROUGH BRUSH SEAL LEAKAGE LINE VENTURI 2 (CALC.)
		TESC. 1	0-2400 PSIG	TESCOM REGULATOR PRESSURE FOR VALVE 269
		TESC.2	0-2400 PSIG	TESCOM REGULATOR PREESURE FOR VALVE 275
		DELTA S	0-1000 PSID	SEAL PISTON DELTA P - DIFFERENCE BETWEEN CH 72 AND CH 82
		DELTA B	0-1000 PSID	BALANCE PISTON DELTA P - DIFFERENCE BETWEEN CH 14 AND CH 11
		HYDPP	0-5000 PSIG	HYDRAULIC PUMP PRESSURE
		HYDPT	TYPE T	HYDRAULIC PUMP TEMPERATURE
	9	B #4	10-60 MIL	40 DEGREE SEAL END PROXIMITY PROBE
	10	B #5	10-60 MIL	130 DEGREE SEAL END PROXIMITY PROBE
	11	B #6	10-60 MIL	220 DEGREE SEAL END PROXIMITY PROBE
		H-27 P	0-30 PSIG	H-27 TRAILER PRESSURE
		H2 P	0-2400 PSIG	H2 TUBE TRAILER PRESSURE
	1	BPAPP	15-80 MIL	BALANCE PISTON AXIAL PROXIMITY PROBE
	5	ZDRASE	0-20 G	ZERO DEGREE RADIAL SEAL END ACCELERATION
	14	IRIG-B		TIME CODE SIGNAL

Note: Some instrumentation ranges were changed for specific configurations.

Appendix B

Uncertainty Analysis

An uncertainty analysis was performed to determine the potential error in key experimental parameters: seal leakage rate, mean pressure at each station, and pressure drop across the seal. The procedure used to determine the uncertainty in the experimental results follows that described by Davidian, Dieck, and Chuang (ref. 23).

The total uncertainty of a measurement is caused by a random (precision) error and a fixed, or systematic (bias), error. The sources of error can be divided into three categories: calibration, data acquisition, and data reduction. No bias errors, however, were included in the analysis because the setup procedure (i.e., electronic calibration) was considered sufficient to make such errors negligible. Furthermore, data reduction errors were assumed to be small. Consequently, only precision errors due to instrumentation calibration and data acquisition were considered.

The precision of the reported leakage rate is a function of several measured parameters because the measurement was obtained using a venturi meter. The flow equation used to calculate the leakage rate m is

$$m = \frac{1}{4} \frac{c_v \pi d_2^2}{\sqrt{1 - \left(\frac{d_2}{d_1}\right)^4}} \sqrt{2\rho\Delta p} \tag{A1}$$

where c_v is the venturi flow coefficient; d_2 is the throat diameter; d_1 is the main tube diameter; ρ is the density; Δp is the pressure drop across the venturi. By inspecting equation (A1), the precision index, which propagates the errors occurring in measured parameters to the calculated parameter through the use of influence coefficients, can be defined as

$$S_m = \left[\left(\frac{\partial m}{\partial d_1} S_{d_1}\right)^2 + \left(\frac{\partial m}{\partial d_2} S_{d_2}\right)^2 + \left(\frac{\partial m}{\partial \Delta p} S_{\Delta p}\right)^2 + \left(\frac{\partial m}{\partial P} S_P\right)^2 + \left(\frac{\partial m}{\partial T} S_T\right)^2\right]^{1/2} \tag{A2}$$

where S_m is the precision index. The primary measurements are the main tube diameter d_1, throat diameter d_2, pressure drop across the venturi Δp, static pressure P, and temperature T. Static pressure and temperature are introduced because density was determined from these two properties and not measured directly. The associated influence coefficients can be determined by differentiating the flow equation with respect to the primary parameters:

$$\frac{\partial m}{\partial d_1} = -\frac{c_v \pi d_2^6}{2 d_1^5} \sqrt{2\rho\Delta p} \left[1 - \left(\frac{d_2}{d_1}\right)^4\right]^{-3/2} \tag{A3}$$

$$\frac{\partial m}{\partial d_2} = \frac{c_v \pi d_2}{2} \sqrt{2\rho\Delta p} \left[1 - \left(\frac{d_2}{d_1}\right)^4\right]^{-3/2} \tag{A4}$$

$$\frac{\partial m}{\partial \Delta p} = \frac{1}{4} \frac{c_v \pi d_2^2 \rho}{\sqrt{2\rho\Delta p}} \left[1 - \left(\frac{d_2}{d_1}\right)^4\right]^{-1/2} \tag{A5}$$

$$\frac{\partial m}{\partial \rho} = \frac{1}{4} \frac{c_v \pi d_2^2 \Delta p}{\sqrt{2\rho\Delta p}} \left[1 - \left(\frac{d_2}{d_1}\right)^4\right]^{-1/2} \tag{A6}$$

Two additional influence coefficients are required to relate density to static pressure and temperature. Simple chain rule provides these relationships:

$$\frac{\partial m}{\partial P} = \frac{\partial m}{\partial \rho} \frac{\partial \rho}{\partial P} \tag{A7}$$

$$\frac{\partial m}{\partial T} = \frac{\partial m}{\partial \rho} \frac{\partial \rho}{\partial T} \tag{A8}$$

Using a fluids properties program called GASP (ref. 24), the partials $\partial\rho/\partial P$ and $\partial\rho/\partial T$ were obtained by perturbing the input pressure and temperature and observing the effect on density.

Following the procedure described by Davidian (ref. 23), the uncertainty U is then determined by applying Student's t value t_{95} to the precision index S_m to assign a confidence level to the numerical value. The relationship

$$U_{99} = t_{95} * S_m \tag{A9}$$

was used to approximate 99 percent coverage.

TABLE IV.—UNCERTAINTY OF EXPERIMENTAL LEAKAGE RATE FOR SEAL CONFIGURATIONS

Seal	Configuration	Leakage rate precision, percent of measured value	
		Venturi 1	Venturi 2
Labyrinth	1	10.5 to 1.0	3.4 to 1.0
Brush	2	12.0 to 2.7	10.2 to 2.1
↓	3	140 to 2.7	2.3 to 2.1
	4	117 to 2.7	3.6 to 2.1
	5	78.5 to 3.5	3.5 to 2.1
	6	95 to 5.8	3.3 to 2.1
	7	3.2 to 2.8	3.0 to 2.2
	8	2.7 to 2.7	2.1 to 2.1
	9	3.5 to 3.3	3.4 to 3.1

TABLE V.—AVERAGE PRESSURE MEASUREMENT UNCERTAINTY AT EACH STATION

Station	Average pressure measurement uncertainty	
	MPa	psi
1	0.008	1.1
2	.043	6.2
3	.026	3.8
4	.068	9.8
5	.011	1.6

TABLE VI.—MEASUREMENT UNCERTAINTY OF PRESSURE DROP BETWEEN STATIONS

Stations	Measurement uncertainty of pressure drop	
	MPa	psi
1 to 2	0.033	4.8
1 to 3	.028	4.1
1 to 5	.014	2.1
2 to 4	.046	6.7
2 to 5	.030	4.4
4 to 5	.047	6.8

The uncertainty of the experimental leakage rate for the seal configurations are presented as a percent of the measured value in table IV. Uncertainty varied for each seal configuration because of the changes in the hardware used to measure leakage rates. Venturi meters and the differential pressure transducers were changed during the test program to better match the leakage characteristics of the particular seal being tested. The intent was to minimize uncertainty in the results. Furthermore, a pair of venturi meters, located in series and downstream of the test seal, were used to provide redundancy. The table includes the uncertainty for each venturi measurement. In addition, a range of uncertainty is given for each case. The uncertainty at low- and high-pressure drops across the seal is reported. Although most of the cases showed small variation, venturi meter 1 for seal configurations 3 through 6 incurred high uncertainty because of the differential pressure transducer used to measure the pressure gradient across the venturi meter. The transducer had a high nonlinearity error associated with it. It was replaced for later tests.

The uncertainty of the mean pressure at each station, which was the average of four or two separate pressure transducers located at different positions around the circumference of the seal, were also determined and are displayed in table V. The uncertainty of the measured pressure drop across the seal is also important. The pressure drop was the difference between the average of two sets of pressure transducers; each set was located at different axial stations. Table VI presents the uncertainty of the measured pressure difference between each station. Although most of the leakage rate data are plotted against the pressure drop measured between stations 1 and 5, some data are not. Thus, the uncertainty in the pressure difference measurement between each station is provided to be complete. In general, the uncertainty of the measured mean and differential pressures is reasonable.

Appendix C

Data Tables—SI Units

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 98.839 kPa

CONFIGURATION NO. 2 Single brush in position 1

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)
125	ALL SCNS	5.43	5.40	84.19	91.48	-0.1	0.000	0.03
126	ALL SCNS	5.37	5.21	84.35	90.20	-0.1	0.072	0.16
127	ALL SCNS	5.31	4.97	83.62	88.77	-0.1	0.110	0.34
128	ALL SCNS	5.27	4.77	83.70	88.65	-0.1	0.135	0.51
129	ALL SCNS	5.23	4.55	83.43	88.39	-0.1	0.162	0.67
130	ALL SCNS	5.19	4.34	83.70	88.70	-0.1	0.181	0.85
131	ALL SCNS	5.16	4.14	83.70	88.74	-0.1	0.197	1.02
132	ALL SCNS	5.13	3.94	83.41	88.41	-0.1	0.208	1.19
133	ALL SCNS	5.15	4.13	83.94	88.75	-0.1	0.193	1.02
134	ALL SCNS	5.18	4.32	83.55	88.68	-0.1	0.176	0.86
135	ALL SCNS	5.21	4.53	83.45	88.18	-0.1	0.155	0.68
136	ALL SCNS	5.25	4.74	83.97	88.59	-0.1	0.133	0.51
137	ALL SCNS	5.29	4.96	83.70	88.41	-0.1	0.105	0.34
138	ALL SCNS	5.35	5.18	83.88	88.88	-0.1	0.066	0.16
139	ALL SCNS	5.42	5.39	84.01	89.90	-0.1	0.000	0.03
140	ALL SCNS	5.47	5.44	83.62	92.72	85.7	0.000	0.03
141	ALL SCNS	5.44	5.28	83.78	90.42	85.7	0.010	0.16
142	ALL SCNS	5.42	5.09	83.75	89.44	85.6	0.032	0.33
143	ALL SCNS	5.41	5.08	83.86	89.22	85.3	0.031	0.33
144	ALL SCNS	5.39	4.87	84.41	90.05	85.9	0.056	0.51
145	ALL SCNS	5.36	4.67	84.00	89.61	85.7	0.078	0.69
146	ALL SCNS	5.34	4.50	83.88	89.41	85.0	0.092	0.84
147	ALL SCNS	5.31	4.26	83.72	89.05	85.5	0.108	1.06
148	ALL SCNS	5.30	4.10	83.44	88.65	84.9	0.117	1.20
149	ALL SCNS	5.30	4.25	83.62	88.77	85.0	0.104	1.05
150	ALL SCNS	5.31	4.46	83.62	88.44	84.8	0.103	0.85
151	ALL SCNS	5.34	4.83	83.27	88.15	85.1	0.070	0.50
152	ALL SCNS	5.38	5.22	83.66	88.85	85.3	0.010	0.16
153	ALL SCNS	5.40	5.22	83.94	89.96	-0.1	0.000	0.18
154	ALL SCNS	5.39	5.04	83.47	89.14	-0.1	0.026	0.34
155	ALL SCNS	5.37	4.86	83.52	88.78	-0.1	0.050	0.51
156	ALL SCNS	5.34	4.51	84.17	88.89	-0.1	0.077	0.82
157	ALL SCNS	5.31	4.29	83.93	88.79	-0.1	0.087	1.02
158	ALL SCNS	5.30	4.11	83.58	88.47	-0.1	0.103	1.18
159	ALL SCNS	5.30	4.27	83.81	88.53	-0.1	0.094	1.03
160	ALL SCNS	5.31	4.48	83.53	88.22	-0.1	0.075	0.83
161	ALL SCNS	5.34	4.84	84.13	88.95	-0.1	0.047	0.49
162	ALL SCNS	5.37	5.22	84.10	89.92	-0.1	0.000	0.16
163	ALL SCNS	5.42	5.43	84.21	98.37	-0.1	0.000	-0.01
164	ALL SCNS	5.39	5.21	84.27	94.11	253.9	0.000	0.18
165	ALL SCNS	5.35	4.86	83.89	91.14	253.8	0.050	0.49
166	ALL SCNS	5.30	4.47	84.00	90.19	252.2	0.081	0.83
167	ALL SCNS	5.28	4.26	83.90	89.81	251.5	0.102	1.02
168	ALL SCNS	5.25	4.05	83.77	89.50	251.5	0.112	1.20
169	ALL SCNS	5.26	4.22	83.98	89.73	252.0	0.103	1.03
170	ALL SCNS	5.26	4.40	84.46	90.46	252.1	0.095	0.86
171	ALL SCNS	5.29	4.77	84.65	91.04	250.5	0.062	0.52
172	ALL SCNS	5.33	5.15	85.29	93.84	250.6	0.015	0.17
173	ALL SCNS	5.33	5.18	87.51	92.94	-0.1	0.008	0.15
174	ALL SCNS	5.30	4.77	88.53	93.07	-0.1	0.051	0.52
175	ALL SCNS	5.27	4.44	89.75	93.91	-0.1	0.073	0.82
176	ALL SCNS	5.25	4.24	91.13	95.06	-0.1	0.089	1.01
177	ALL SCNS	5.24	4.06	92.96	96.69	-0.1	0.086	1.18
178	ALL SCNS	5.24	4.21	94.83	98.43	-0.1	0.087	1.03

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 98.839 kPa

CONFIGURATION NO. 2 Single brush in position 1

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)
179	ALL SCNS	5.25	4.40	97.06	100.39	-0.1	0.071	0.85
180	ALL SCNS	5.27	4.75	99.37	102.53	-0.1	0.048	0.51
181	ALL SCNS	5.30	5.13	102.24	105.44	-0.1	0.014	0.17
182	ALL SCNS	5.50	5.34	82.08	88.19	-0.1	0.032	0.16
183	ALL SCNS	5.51	5.16	82.40	88.06	-0.2	0.060	0.35
184	ALL SCNS	5.51	5.16	82.28	88.08	-0.1	0.060	0.35
185	ALL SCNS	5.51	5.00	82.38	88.21	-0.1	0.075	0.51
186	ALL SCNS	5.51	4.83	82.78	88.13	-0.1	0.091	0.68
187	ALL SCNS	5.49	4.64	83.08	88.40	-0.1	0.105	0.85
188	ALL SCNS	5.48	4.43	82.90	88.23	-0.1	0.119	1.04
189	ALL SCNS	5.47	4.27	82.81	88.09	-0.1	0.120	1.19
190	ALL SCNS	5.48	4.45	82.77	88.05	-0.1	0.112	1.03
191	ALL SCNS	5.50	4.65	82.95	88.06	-0.1	0.103	0.85
192	ALL SCNS	5.52	4.83	83.34	88.60	-0.1	0.091	0.69
193	ALL SCNS	5.54	5.02	83.35	88.69	-0.1	0.077	0.52
194	ALL SCNS	5.56	5.23	83.36	88.92	-0.1	0.059	0.33
195	ALL SCNS	5.60	5.42	83.29	89.13	-0.1	0.035	0.18
196	ALL SCNS	5.51	5.35	82.18	88.01	81.5	0.044	0.17
197	ALL SCNS	5.51	4.99	82.24	87.77	80.6	0.085	0.52
198	ALL SCNS	5.52	5.01	82.87	89.93	250.8	0.082	0.51
199	ALL SCNS	5.52	5.35	82.72	91.01	249.2	0.039	0.17
200	ALL SCNS	5.52	5.34	84.76	101.71	405.2	0.037	0.18
201	ALL SCNS	5.52	5.00	84.45	97.71	423.2	0.079	0.52
202	ALL SCNS	5.49	4.64	84.16	94.82	419.5	0.111	0.85
203	ALL SCNS	5.47	4.44	84.05	94.03	418.8	0.116	1.02
204	ALL SCNS	5.44	4.22	84.03	93.65	418.1	0.129	1.23
205	ALL SCNS	5.45	4.40	84.24	94.20	420.0	0.116	1.05
206	ALL SCNS	5.46	4.58	84.35	94.56	420.3	0.122	0.87
207	ALL SCNS	5.49	5.00	84.74	96.31	419.3	0.085	0.49
208	ALL SCNS	5.55	5.39	85.82	102.34	417.5	0.038	0.16
209	ALL SCNS	5.54	5.36	83.47	89.72	-0.1	0.045	0.18
210	ALL SCNS	5.49	4.98	83.33	88.74	-0.2	0.088	0.51
211	ALL SCNS	5.45	4.61	83.37	89.18	-0.2	0.114	0.84
212	ALL SCNS	5.43	4.40	83.12	88.59	-0.2	0.115	1.03
213	ALL SCNS	5.41	4.25	83.20	88.72	-0.2	0.133	1.17
214	ALL SCNS	5.42	4.38	83.28	88.62	-0.2	0.115	1.05
215	ALL SCNS	5.44	4.59	83.40	88.65	-0.1	0.119	0.85
216	ALL SCNS	5.47	4.94	83.73	88.95	-0.1	0.086	0.53
217	ALL SCNS	5.53	5.36	83.95	89.62	-0.1	0.040	0.17
218	ALL SCNS	5.59	5.59	84.37	98.43	-0.1	0.000	0.00
219	ALL SCNS	5.58	5.43	90.02	121.32	591.3	0.037	0.15
220	ALL SCNS	5.49	4.98	89.00	109.50	585.1	0.083	0.51
221	ALL SCNS	5.43	4.58	89.70	106.97	587.9	0.107	0.85
222	ALL SCNS	5.38	4.36	90.85	106.60	584.5	0.119	1.03
223	ALL SCNS	5.34	4.15	92.18	106.79	582.3	0.132	1.19
224	ALL SCNS	5.33	4.30	94.35	109.08	585.7	0.123	1.03
225	ALL SCNS	5.33	4.48	97.17	112.40	583.5	0.111	0.85
226	ALL SCNS	5.33	4.82	101.24	118.79	591.7	0.083	0.51
227	ALL SCNS	5.36	5.19	105.40	128.95	627.8	0.044	0.17
228	ALL SCNS	5.31	5.14	109.05	113.05	-0.1	0.046	0.17
229	ALL SCNS	5.27	4.75	113.15	116.45	-0.1	0.088	0.51
230	ALL SCNS	5.23	4.37	117.60	120.31	-0.1	0.109	0.86
231	ALL SCNS	5.22	4.19	121.83	123.87	-0.1	0.113	1.03
232	ALL SCNS	5.22	4.02	125.34	126.53	-0.1	0.118	1.20
233	ALL SCNS	5.22	4.19	127.37	128.36	-0.1	0.108	1.04
234	ALL SCNS	5.23	4.38	129.42	130.54	-0.1	0.096	0.85
235	ALL SCNS	5.25	4.75	131.80	133.06	-0.1	0.072	0.50
236	ALL SCNS	5.28	5.12	133.71	135.43	-0.1	0.037	0.16
237	ALL SCNS	5.33	5.33	134.96	139.24	-0.1	0.000	0.00

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 97.012 kPa

CONFIGURATION NO. 3 2 Brushes far apart at stations 2 & 5

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 3 (MPa)	AVG PRESS STATION 4 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 3 (K)	AVG TEMP STATION 4 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)
238	ALL SCNS	5.37	5.36	5.37	5.34	83.11	85.36	84.33	89.815	-0.2	0.00
239	ALL SCNS	5.37	5.30	5.31	5.21	83.13	84.09	83.55	87.221	-0.1	0.03
240	ALL SCNS	5.37	5.22	5.23	5.03	82.99	83.76	83.23	86.402	-0.1	0.06
241	ALL SCNS	5.37	5.15	5.16	4.86	82.95	83.70	83.26	86.416	-0.1	0.07
242	ALL SCNS	5.37	5.09	5.10	4.70	83.09	83.69	83.36	86.399	-0.2	0.08
243	ALL SCNS	5.37	5.03	5.03	4.52	82.94	83.58	83.27	86.330	-0.2	0.10
244	ALL SCNS	5.37	4.97	4.97	4.34	83.05	83.62	83.34	86.514	-0.2	0.10
245	ALL SCNS	5.37	4.92	4.93	4.17	82.94	83.53	83.25	86.474	-0.2	0.11
246	ALL SCNS	5.37	4.86	4.87	4.00	82.62	83.29	83.04	86.470	-0.2	0.12
247	ALL SCNS	5.37	4.87	4.87	3.83	82.75	83.34	83.12	86.547	-0.1	0.13
248	ALL SCNS	5.36	4.82	4.83	3.65	82.89	83.47	83.25	86.777	-0.2	0.14
249	ALL SCNS	5.37	4.88	4.89	3.84	82.73	83.39	83.13	86.464	-0.2	0.13
250	ALL SCNS	5.37	4.93	4.94	4.01	82.86	83.46	83.15	86.487	-0.2	0.12
251	ALL SCNS	5.37	4.99	4.99	4.20	82.74	83.34	83.04	86.323	-0.2	0.11
252	ALL SCNS	5.37	5.04	5.04	4.35	82.80	83.35	83.09	86.452	-0.2	0.10
253	ALL SCNS	5.37	5.09	5.10	4.53	82.85	83.44	83.15	86.555	-0.2	0.09
254	ALL SCNS	5.37	5.15	5.15	4.70	82.76	83.32	83.10	86.408	-0.2	0.08
255	ALL SCNS	5.37	5.20	5.21	4.88	82.81	83.42	83.11	86.513	-0.2	0.06
256	ALL SCNS	5.37	5.25	5.26	5.04	82.77	83.42	83.00	86.513	-0.1	0.05
257	ALL SCNS	5.37	5.31	5.32	5.22	82.79	83.55	83.19	86.854	-0.1	0.02
258	ALL SCNS	5.37	5.37	5.38	5.36	82.74	84.54	83.72	90.163	-0.1	0.00
259	ALL SCNS	5.37	5.38	5.39	5.38	82.87	93.99	97.68	100.211	-0.1	0.00
260	ALL SCNS	5.37			5.23	82.86	88.03	87.87	93.886	85.1	0.00
261	ALL SCNS	5.37			4.86	82.84	84.43	84.30	88.210	85.2	0.02
262	ALL SCNS	5.37			4.51	82.82	83.72	83.60	86.877	84.8	0.05
263	ALL SCNS	5.37			4.18	82.91	83.60	83.45	86.561	84.4	0.06
264	ALL SCNS	5.37			3.84	82.86	83.53	83.37	86.354	84.3	0.08
265	ALL SCNS	5.37			3.67	83.02	83.68	83.50	86.376	83.9	0.08
266	ALL SCNS	5.37			3.47	83.20	83.88	83.64	86.593	83.5	0.09
267	ALL SCNS	5.37			3.34	83.26	83.87	83.79	86.514	81.3	0.09
268	ALL SCNS	5.37			3.82	83.36	84.00	83.80	86.562	83.5	0.08
269	ALL SCNS	5.37			4.18	83.35	83.86	83.73	86.434	83.0	0.07
270	ALL SCNS	5.37			4.53	83.52	84.13	83.94	86.728	84.1	0.05
271	ALL SCNS	5.37			4.88	83.42	84.07	83.92	86.932	84.1	0.03
272	ALL SCNS	5.37			5.22	83.48	85.38	85.27	89.239	84.3	0.01
273	ALL SCNS	5.38			5.38	84.20	106.06	106.23	101.822	85.0	0.00
274	ALL SCNS	5.37	5.30	5.30	5.21	83.59	84.92	84.33	89.174	-0.1	0.01
275	ALL SCNS	5.37	5.14	5.14	4.86	83.48	84.24	83.86	87.295	-0.1	0.03
276	ALL SCNS	5.37	5.01	5.01	4.51	83.66	84.26	84.06	86.931	-0.1	0.05
277	ALL SCNS	5.37	4.89	4.90	4.17	83.68	84.28	84.11	86.879	-0.1	0.06
278	ALL SCNS	5.37	4.76	4.76	3.83	83.75	84.33	84.17	86.824	-0.1	0.08
279	ALL SCNS	5.36	4.64	4.64	3.46	83.83	84.39	84.29	87.053	-0.1	0.09
280	ALL SCNS	5.37	4.77	4.78	3.84	84.00	84.47	84.33	87.118	-0.1	0.08
281	ALL SCNS	5.37	4.91	4.91	4.19	84.14	84.57	84.57	87.160	-0.1	0.06
282	ALL SCNS	5.37	5.03	5.03	4.52	84.83	85.32	85.18	87.779	-0.1	0.05
283	ALL SCNS	5.37	5.16	5.17	4.89	85.72	86.24	86.05	88.662	-0.1	0.03
284	ALL SCNS	5.37	5.29	5.30	5.22	87.63	88.26	87.94	90.937	-0.1	0.01
285	ALL SCNS	5.37	5.38	5.39	5.38	89.28	94.13	95.89	99.543	-0.1	0.00
287	ALL SCNS	5.59			5.43	83.88	93.63	93.53	104.062	253.9	0.02
288	ALL SCNS	5.59			5.10	83.88	87.42	87.32	94.244	247.5	0.04
289	ALL SCNS	5.59			4.74	83.63	85.73	85.61	90.840	246.8	0.05
290	ALL SCNS	5.59			4.39	83.73	85.51	85.43	89.775	250.9	0.07
291	ALL SCNS	5.59			4.04	83.68	85.11	85.15	88.875	249.8	0.08
292	ALL SCNS	5.58			3.68	83.75	85.18	85.02	88.678	249.8	0.09

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 97.012 kPa

CONFIGURATION NO. 3 2 Brushes far apart at stations 2 & 5

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 3 (MPa)	AVG PRESS STATION 4 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 3 (K)	AVG TEMP STATION 4 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)
293	ALL SCNS	5.59			4.05	83.70	85.05	84.98	88.617	249.0	0.08
294	ALL SCNS	5.59			4.39	83.65	84.99	84.92	88.816	248.4	0.08
295	ALL SCNS	5.59			4.72	83.57	85.07	85.00	89.035	248.3	0.06
296	ALL SCNS	5.59			5.08	83.62	85.51	85.48	90.489	248.5	0.05
297	ALL SCNS	5.59			5.43	83.89	90.15	90.09	97.375	244.9	0.02
298	ALL SCNS	5.59			5.60	84.81	117.45	117.76	116.825	249.9	0.01
299	ALL SCNS	5.58	5.52	5.52	5.42	83.07	84.10	83.75	88.798	-0.1	0.02
300	ALL SCNS	5.58	5.38	5.38	5.07	83.00	83.61	83.44	87.338	-0.1	0.04
301	ALL SCNS	5.58	5.28	5.28	4.72	83.60	83.90	83.88	87.179	-0.1	0.05
302	ALL SCNS	5.58	5.20	5.20	4.37	83.93	83.97	83.98	87.096	-0.1	0.06
303	ALL SCNS	5.57	5.10	5.09	4.04	83.66	83.81	83.80	86.742	-0.1	0.07
304	ALL SCNS	5.54	4.96	4.96	3.58	83.43	83.67	83.48	86.424	-0.1	0.08
305	ALL SCNS	5.54	5.00	5.00	3.68	83.36	83.60	83.44	86.160	-0.1	0.08
306	ALL SCNS	5.55	5.11	5.10	4.04	83.62	83.79	83.71	86.295	-0.2	0.07
307	ALL SCNS	5.56	5.20	5.20	4.37	83.65	83.84	83.71	86.236	-0.2	0.06
308	ALL SCNS	5.57	5.29	5.29	4.71	83.69	83.86	83.84	86.174	-0.2	0.05
309	ALL SCNS	5.60	5.41	5.41	5.09	83.77	84.03	83.81	86.525	-0.2	0.04
310	ALL SCNS	5.67	5.60	5.60	5.51	84.16	84.78	84.35	87.638	-0.2	0.02
311	ALL SCNS	5.59	5.59	5.59	5.57	83.34	86.86	86.52	95.284	-0.2	0.01
312	ALL SCNS	5.61			5.45	86.43	103.40	103.25	119.998	418.0	0.02
313	ALL SCNS	5.60			5.11	86.18	94.89	94.74	107.660	413.4	0.04
314	ALL SCNS	5.60			4.73	85.82	92.12	91.98	102.138	413.4	0.05
315	ALL SCNS	5.60			4.42	85.93	91.33	91.38	100.140	415.7	0.06
316	ALL SCNS	5.58			4.06	85.81	90.67	90.71	98.594	417.7	0.07
317	ALL SCNS	5.56			3.86	85.92	90.12	90.15	97.029	415.4	0.08
318	ALL SCNS	5.56			4.04	86.27	90.59	90.63	97.663	415.8	0.07
319	ALL SCNS	5.57			4.39	86.32	91.11	91.09	98.800	416.5	0.06
320	ALL SCNS	5.58			4.73	86.44	91.76	91.76	100.217	415.7	0.06
321	ALL SCNS	5.60			5.09	86.85	93.62	93.62	104.313	417.0	0.04
322	ALL SCNS	5.63			5.47	87.40	101.90	101.72	117.054	412.7	0.02
323	ALL SCNS	5.66			5.67	91.72	145.76	146.35	144.767	420.2	0.01
324	ALL SCNS	5.58	5.51	5.51	5.41	83.61	84.83	84.39	89.037	-0.2	0.02
325	ALL SCNS	5.59	5.39	5.38	5.07	83.63	84.31	84.16	88.060	-0.1	0.04
326	ALL SCNS	5.58	5.28	5.28	4.71	83.69	84.17	84.08	87.335	-0.1	0.05
327	ALL SCNS	5.58	5.23	5.22	4.41	83.67	84.03	83.99	86.734	-0.1	0.06
328	ALL SCNS	5.58	5.13	5.13	4.03	84.07	84.14	84.22	86.850	-0.1	0.07
329	ALL SCNS	5.58	5.09	5.09	3.86	84.17	84.26	84.33	86.867	-0.1	0.07
330	ALL SCNS	5.58	5.15	5.15	4.05	84.38	84.47	84.48	87.096	-0.1	0.07
331	ALL SCNS	5.59	5.23	5.23	4.37	83.70	83.92	83.88	85.575	-0.1	0.06
332	ALL SCNS	5.59	5.33	5.33	4.74	83.51	83.85	83.72	85.520	-0.1	0.05
333	ALL SCNS	5.59	5.40	5.40	5.08	83.64	84.10	83.95	86.127	-0.1	0.04
334	ALL SCNS	5.59	5.52	5.52	5.42	83.75	84.54	84.16	87.258	-0.1	0.03
335	ALL SCNS	5.59	5.59	5.59	5.58	83.63	87.19	87.00	94.358	-0.1	0.02
336	ALL SCNS	5.62			5.47	91.24	116.93	116.87	133.276	588.4	0.02
337	ALL SCNS	5.61			5.11	90.42	104.44	104.36	122.324	584.6	0.04
338	ALL SCNS	5.59			4.74	89.82	100.54	100.68	116.322	587.1	0.05
339	ALL SCNS	5.57			4.41	89.70	99.44	99.58	113.017	591.9	0.07
340	ALL SCNS	5.55			4.03	89.26	98.10	98.19	110.128	589.2	0.08
341	ALL SCNS	5.54			3.83	89.00	97.39	97.49	108.720	588.9	0.08
342	ALL SCNS	5.53			3.99	89.37	98.07	98.17	109.774	592.2	0.08
343	ALL SCNS	5.53			4.36	89.78	99.45	99.57	112.343	594.2	0.07
344	ALL SCNS	5.53			4.69	90.06	100.79	100.99	115.205	592.8	0.06
345	ALL SCNS	5.53			5.04	90.41	102.30	102.34	118.573	592.4	0.05
346	ALL SCNS	5.56			5.39	92.09	115.11	115.04	131.803	604.1	0.02
347	ALL SCNS	5.55			5.39	91.72	113.89	113.82	131.555	590.4	0.02
348	ALL SCNS	5.57			5.58	97.73	192.36	193.28	190.752	580.6	0.00
349	ALL SCNS	5.52	5.45	5.45	5.36	84.87	86.67	85.87	93.094	-0.1	0.02
350	ALL SCNS	5.50	5.30	5.29	4.97	84.68	85.26	84.87	89.051	-0.1	0.04
351	ALL SCNS	5.48	5.23	5.23	4.62	84.51	84.85	84.54	87.512	-0.1	0.05
352	ALL SCNS	5.46	5.14	5.14	4.26	84.32	84.63	84.24	86.824	-0.1	0.06
353	ALL SCNS	5.44	5.06	5.06	3.89	84.33	84.49	84.29	86.554	-0.1	0.07
354	ALL SCNS	5.42	5.02	5.02	3.70	84.69	84.87	84.64	86.661	-0.1	0.07
355	ALL SCNS	5.41	5.04	5.04	3.88	85.10	85.22	84.92	87.067	-0.1	0.07
356	ALL SCNS	5.41	5.08	5.08	4.21	85.65	85.67	85.51	87.505	-0.1	0.06
357	ALL SCNS	5.39	5.14	5.13	4.54	87.08	87.15	86.98	88.969	-0.1	0.05
358	ALL SCNS	5.40	5.22	5.21	4.90	88.34	88.35	88.26	90.196	-0.1	0.04
359	ALL SCNS	5.40	5.33	5.33	5.23	90.05	90.18	89.98	92.472	-0.1	0.03
360	ALL SCNS	5.41	5.42	5.42	5.41	92.37	94.29	94.70	101.744	-0.1	0.02

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 99.280 kPa

CONFIGURATION NO. 4 2 Brushes tightly packed .. positions 3 & 4

FLUID: NITROGEN

RDG AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 2 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 2 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)	DELTA-P STA 1-2 (MPd)
362 ALL SCNS	5.59	5.59	5.42	83.88	84.62	92.21	-0.1	0.057	0.16	0.00
363 ALL SCNS	5.55	5.55	5.20	83.65	84.34	91.65	-0.1	0.089	0.35	0.00
364 ALL SCNS	5.53	5.53	5.01	83.51	84.12	91.20	-0.1	0.107	0.51	0.00
365 ALL SCNS	5.51	5.51	4.81	83.34	83.98	91.01	-0.1	0.124	0.70	0.00
366 ALL SCNS	5.48	5.49	4.62	83.27	83.95	90.81	-0.1	0.141	0.86	0.00
367 ALL SCNS	5.46	5.46	4.43	83.15	83.77	90.74	-0.1	0.156	1.03	0.00
368 ALL SCNS	5.44	5.44	4.22	83.05	83.55	90.67	-0.1	0.167	1.22	0.00
369 ALL SCNS	5.43	5.43	4.07	82.94	83.57	90.78	-0.1	0.172	1.36	0.00
370 ALL SCNS	5.41	5.41	3.85	83.01	83.64	90.84	-0.1	0.178	1.56	0.00
371 ALL SCNS	5.37	5.37	3.66	82.90	83.44	90.65	-0.1	0.179	1.71	0.00
372 ALL SCNS	5.38	5.39	3.87	82.96	83.56	90.62	-0.1	0.174	1.52	0.00
373 ALL SCNS	5.40	5.40	4.02	83.04	83.53	90.60	-0.1	0.168	1.38	0.00
374 ALL SCNS	5.41	5.41	4.20	83.02	83.49	90.63	-0.1	0.157	1.21	0.00
375 ALL SCNS	5.43	5.43	4.42	83.03	83.74	90.72	-0.1	0.148	1.02	0.00
376 ALL SCNS	5.45	5.45	4.60	82.99	83.66	90.63	-0.1	0.135	0.85	0.00
377 ALL SCNS	5.47	5.48	4.79	83.16	83.83	90.84	-0.1	0.120	0.68	0.00
378 ALL SCNS	5.51	5.51	5.01	83.18	83.70	90.93	-0.1	0.100	0.49	0.00
379 ALL SCNS	5.54	5.55	5.22	83.36	83.89	91.34	-0.1	0.075	0.33	0.00
380 ALL SCNS	5.58	5.58	5.42	83.39	84.03	91.75	-0.1	0.050	0.16	0.00
381 ALL SCNS	5.64	5.64	5.64	83.60	84.75	97.54	-0.1	0.002	0.00	0.00
382 ALL SCNS	5.57	5.57	5.41	83.22	84.02	95.19	84.1	0.024	0.16	0.00
383 ALL SCNS	5.54	5.53	5.04	83.05	83.66	92.74	83.9	0.050	0.50	0.01
384 ALL SCNS	5.50	5.50	4.61	82.96	83.57	92.00	85.9	0.081	0.89	0.00
385 ALL SCNS	5.47	5.47	4.25	82.80	83.52	91.64	85.3	0.097	1.23	0.00
386 ALL SCNS	5.46	5.45	3.90	82.85	83.44	91.61	83.9	0.108	1.55	0.00
387 ALL SCNS	5.45	5.45	3.73	82.74	83.44	91.50	81.9	0.114	1.71	0.00
388 ALL SCNS	5.46	5.45	3.92	82.86	83.48	91.43	83.9	0.106	1.53	0.00
389 ALL SCNS	5.47	5.47	4.26	83.03	83.65	91.38	83.5	0.094	1.21	0.00
390 ALL SCNS	5.49	5.49	4.65	83.15	83.74	91.53	83.5	0.079	0.84	0.00
391 ALL SCNS	5.51	5.51	5.01	83.27	83.78	91.83	82.5	0.060	0.51	0.00
392 ALL SCNS	5.56	5.56	5.40	83.50	84.15	93.93	83.8	0.026	0.15	0.00
393 ALL SCNS	5.56	5.57	5.40	83.72	84.40	92.40	-0.2	0.028	0.16	-0.01
394 ALL SCNS	5.54	5.54	5.01	83.58	84.16	91.94	-0.2	0.060	0.52	-0.01
395 ALL SCNS	5.50	5.50	4.64	83.54	84.18	91.35	-0.2	0.076	0.86	-0.01
396 ALL SCNS	5.47	5.48	4.26	83.44	83.97	91.35	-0.2	0.099	1.21	-0.01
397 ALL SCNS	5.45	5.45	3.91	83.31	83.90	91.30	-0.2	0.109	1.54	-0.01
398 ALL SCNS	5.44	5.44	3.72	83.18	83.72	91.24	-0.2	0.115	1.71	-0.01
399 ALL SCNS	5.45	5.45	3.91	83.21	83.74	91.27	-0.2	0.108	1.54	-0.01
400 ALL SCNS	5.46	5.47	4.28	83.20	83.77	91.12	-0.2	0.095	1.19	-0.01
401 ALL SCNS	5.48	5.49	4.63	83.29	83.72	91.21	-0.2	0.079	0.85	-0.01
402 ALL SCNS	5.51	5.51	5.00	83.42	83.91	91.30	-0.2	0.059	0.51	0.00
403 ALL SCNS	5.56	5.56	5.41	83.60	84.15	92.70	-0.2	0.024	0.14	-0.01
404 ALL SCNS	5.59	5.59	5.59	83.63	84.84	98.91	-0.2	0.003	0.00	-0.01
405 ALL SCNS	5.57	5.52	5.40	84.27	85.15	103.12	254.5	0.026	0.17	0.05
406 ALL SCNS	5.54	5.49	5.04	83.86	84.60	97.16	249.0	0.047	0.50	0.05
407 ALL SCNS	5.50	5.45	4.64	83.69	84.31	95.02	249.0	0.071	0.87	0.05
408 ALL SCNS	5.46	5.41	4.27	83.54	84.30	93.76	250.1	0.096	1.20	0.05
409 ALL SCNS	5.44	5.39	3.90	83.45	84.13	93.30	247.5	0.109	1.55	0.05
410 ALL SCNS	5.43	5.38	3.71	83.36	84.09	93.14	248.8	0.113	1.72	0.05
411 ALL SCNS	5.44	5.39	3.92	83.41	84.14	93.24	249.4	0.105	1.52	0.05
412 ALL SCNS	5.45	5.40	4.26	83.46	84.15	93.45	248.6	0.093	1.19	0.05
413 ALL SCNS	5.47	5.42	4.63	83.77	84.40	94.03	249.4	0.078	0.83	0.05
414 ALL SCNS	5.49	5.44	4.99	83.84	84.47	94.86	248.0	0.058	0.50	0.05
415 ALL SCNS	5.54	5.49	5.38	84.33	84.99	101.13	248.0	0.023	0.15	0.05

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 99.280 kPa

CONFIGURATION NO. 4 2 Brushes tightly packed .. positions 3 & 4

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 2 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 2 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)	DELTA-P STA 1-2 (MPd)
416	ALL SCNS	5.54	5.55	5.38	83.59	83.87	93.09	-0.1	0.025	0.16	-0.01
417	ALL SCNS	5.51	5.52	5.01	83.35	83.76	92.30	-0.1	0.050	0.51	-0.01
418	ALL SCNS	5.48	5.49	4.64	83.33	83.62	91.97	-0.1	0.073	0.85	-0.01
419	ALL SCNS	5.46	5.46	4.25	83.43	83.81	91.76	-0.1	0.090	1.20	-0.01
420	ALL SCNS	5.43	5.44	3.89	83.32	83.70	91.61	-0.1	0.102	1.55	-0.01
421	ALL SCNS	5.42	5.43	3.71	83.37	83.72	91.73	-0.1	0.107	1.71	-0.01
422	ALL SCNS	5.42	5.43	3.88	83.50	83.83	91.75	-0.1	0.101	1.54	-0.01
423	ALL SCNS	5.43	5.44	4.25	83.50	83.81	91.85	-0.1	0.088	1.18	-0.01
424	ALL SCNS	5.45	5.46	4.61	83.62	84.02	91.97	-0.1	0.074	0.84	-0.01
425	ALL SCNS	5.47	5.48	4.97	83.70	83.98	92.14	-0.1	0.054	0.50	-0.01
426	ALL SCNS	5.51	5.52	5.36	83.81	84.10	93.68	-0.1	0.025	0.15	-0.01
427	ALL SCNS	5.54	5.54	5.54	83.81	85.04	99.73	-0.1	0.002	0.00	-0.01
428	ALL SCNS	5.54	5.42	5.38	88.26	89.42	110.95	419.7	0.026	0.16	0.12
429	ALL SCNS	5.46	5.34	4.97	87.66	88.68	99.73	419.1	0.052	0.50	0.12
430	ALL SCNS	5.43	5.30	4.58	86.81	87.86	95.36	420.7	0.077	0.84	0.12
431	ALL SCNS	5.38	5.25	4.19	86.35	87.39	93.26	419.6	0.096	1.18	0.12
432	ALL SCNS	5.35	5.22	3.81	85.85	86.94	91.84	418.9	0.110	1.54	0.13
433	ALL SCNS	5.33	5.20	3.61	85.71	86.81	91.22	417.9	0.116	1.72	0.13
434	ALL SCNS	5.34	5.21	3.81	86.04	87.08	91.90	418.8	0.108	1.53	0.13
435	ALL SCNS	5.35	5.22	4.18	85.98	86.99	92.56	419.4	0.094	1.17	0.13
436	ALL SCNS	5.37	5.24	4.52	86.42	87.48	93.82	418.8	0.080	0.85	0.12
437	ALL SCNS	5.40	5.28	4.91	87.58	88.54	98.38	417.6	0.053	0.49	0.12
438	ALL SCNS	5.44	5.32	5.28	88.35	89.30	108.96	417.3	0.026	0.16	0.12
439	ALL SCNS	5.48	5.48	5.48	85.64	94.95	111.63	-0.1	0.002	-0.01	-0.01
440	ALL SCNS	5.44	5.45	5.25	84.28	84.49	86.94	-0.1	0.029	0.18	-0.01
441	ALL SCNS	5.40	5.41	4.89	84.51	84.56	85.49	-0.1	0.054	0.51	-0.01
442	ALL SCNS	5.37	5.37	4.50	84.01	84.13	84.48	-0.1	0.081	0.87	-0.01
443	ALL SCNS	5.34	5.35	4.13	83.91	84.01	83.96	-0.1	0.096	1.21	-0.01
444	ALL SCNS	5.32	5.33	3.78	84.36	84.45	84.36	-0.1	0.109	1.55	-0.01
445	ALL SCNS	5.31	5.32	3.59	84.14	84.18	84.28	-0.1	0.114	1.72	-0.01
446	ALL SCNS	5.32	5.33	3.79	84.65	84.57	84.48	-0.1	0.106	1.53	-0.01
447	ALL SCNS	5.33	5.34	4.13	84.49	84.53	84.48	-0.1	0.094	1.20	-0.01
448	ALL SCNS	5.35	5.36	4.49	84.34	84.39	84.54	-0.1	0.079	0.86	-0.01
449	ALL SCNS	5.39	5.39	4.87	84.89	84.82	85.29	-0.1	0.053	0.51	-0.01
450	ALL SCNS	5.43	5.43	5.26	85.08	85.05	86.97	-0.1	0.026	0.17	-0.01
451	ALL SCNS	5.47	5.25	5.31	93.34	94.83	128.38	591.5	0.024	0.16	0.21
452	ALL SCNS	5.43	5.21	4.93	91.23	92.76	115.68	583.4	0.051	0.49	0.21
453	ALL SCNS	5.39	5.17	4.54	89.88	91.38	107.40	579.1	0.079	0.85	0.21
454	ALL SCNS	5.36	5.14	4.19	89.86	91.38	105.23	586.3	0.093	1.17	0.22
455	ALL SCNS	5.33	5.11	3.81	88.96	90.48	102.57	583.8	0.109	1.52	0.22
456	ALL SCNS	5.31	5.08	3.61	88.75	90.22	101.45	584.2	0.116	1.70	0.22
457	ALL SCNS	5.31	5.08	3.78	89.22	90.70	102.68	590.1	0.109	1.52	0.23
458	ALL SCNS	5.32	5.09	4.16	89.66	91.08	104.64	592.3	0.094	1.16	0.23
459	ALL SCNS	5.33	5.11	4.49	89.97	91.36	107.00	590.1	0.079	0.84	0.22
460	ALL SCNS	5.35	5.13	4.87	91.31	92.75	113.50	589.7	0.056	0.48	0.22
461	ALL SCNS	5.39	5.17	5.22	93.24	94.68	127.10	589.8	0.026	0.16	0.21
462	ALL SCNS	5.35	5.36	5.19	84.87	84.99	87.86	-0.1	0.030	0.16	-0.01
463	ALL SCNS	5.32	5.33	4.80	84.39	84.40	85.71	-0.1	0.058	0.52	-0.01
464	ALL SCNS	5.28	5.29	4.42	84.11	84.29	84.52	-0.1	0.085	0.86	-0.01
465	ALL SCNS	5.26	5.26	4.04	83.80	84.03	84.03	-0.1	0.101	1.22	-0.01
466	ALL SCNS	5.23	5.24	3.67	83.63	83.81	83.81	-0.1	0.113	1.57	-0.01
467	ALL SCNS	5.22	5.23	3.51	83.59	83.75	83.68	-0.1	0.117	1.71	-0.01
468	ALL SCNS	5.22	5.23	3.68	83.84	83.91	83.85	-0.1	0.111	1.54	-0.01
469	ALL SCNS	5.24	5.24	4.04	83.86	83.98	84.02	-0.1	0.097	1.20	-0.01
470	ALL SCNS	5.25	5.26	4.42	83.99	84.11	84.11	-0.1	0.081	0.83	-0.01
471	ALL SCNS	5.28	5.29	4.78	84.03	84.00	84.29	-0.1	0.059	0.50	-0.01
472	ALL SCNS	5.32	5.32	5.15	83.97	84.04	85.16	-0.1	0.029	0.17	-0.01
473	ALL SCNS	5.35	5.36	5.35	84.59	86.66	93.07	-0.1	0.000	0.00	-0.01

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 99.039 kPa

CONFIGURATION NO. 5 3 Brushes equally space: pos 1,3,5

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 2 (MPa)	AVG PRESS STATION 4 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 2 (K)	AVG TEMP STATION 4 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)
475	ALL SCNS	5.50	5.50	5.50	5.49	85.12	89.34	92.35	97.688	-0.1	0.00
476	ALL SCNS	5.37	5.36	5.34	5.32	83.20	84.10	86.24	93.088	-0.1	0.01
477	ALL SCNS	5.37	5.32	5.28	5.19	83.13	83.59	84.55	87.980	-0.1	0.02
478	ALL SCNS	5.37	5.22	5.09	4.84	83.05	83.55	83.82	86.228	-0.1	0.03
479	ALL SCNS	5.37	5.14	4.92	4.48	82.90	83.45	83.62	85.639	-0.1	0.05
480	ALL SCNS	5.37	5.12	4.87	4.33	83.08	83.60	83.66	85.440	-0.1	0.06
481	ALL SCNS	5.37	5.09	4.79	4.17	83.08	83.56	83.61	85.401	-0.1	0.06
482	ALL SCNS	5.37	5.05	4.71	3.98	83.10	83.52	83.62	85.327	-0.1	0.07
483	ALL SCNS	5.37	5.02	4.64	3.81	82.92	83.42	83.45	85.236	-0.1	0.07
484	ALL SCNS	5.37	4.96	4.67	3.63	82.95	83.39	83.41	85.176	-0.1	0.08
485	ALL SCNS	5.37	4.93	4.63	3.47	82.91	83.41	83.39	85.158	-0.1	0.08
486	ALL SCNS	5.37	4.97	4.70	3.65	82.92	83.43	83.42	85.154	-0.1	0.08
487	ALL SCNS	5.37	5.01	4.77	3.84	82.95	83.43	83.37	85.110	-0.1	0.07
488	ALL SCNS	5.37	5.06	4.84	4.02	82.99	83.48	83.51	85.171	-0.1	0.07
489	ALL SCNS	5.37	5.10	4.89	4.17	83.02	83.45	83.48	85.249	-0.1	0.06
490	ALL SCNS	5.37	5.15	4.91	4.33	82.88	83.37	83.41	85.149	-0.1	0.06
491	ALL SCNS	5.37	5.20	4.98	4.51	82.89	83.39	83.49	85.327	-0.1	0.05
492	ALL SCNS	5.37	5.27	5.14	4.86	82.83	83.37	83.43	85.440	-0.1	0.04
493	ALL SCNS	5.37	5.34	5.30	5.20	82.83	83.46	83.76	86.267	-0.1	0.02
494	ALL SCNS	5.37	5.36	5.33	5.29	82.86	83.62	84.28	87.411	-0.1	0.01
495	ALL SCNS	5.37	5.38	5.38	5.38	82.86	88.14	94.18	96.327	-0.1	0.00
496	ALL SCNS	5.37			5.19	82.80	85.29	86.93	90.628	83.2	0.02
497	ALL SCNS	5.37			4.84	82.80	84.29	84.79	87.261	81.9	0.03
498	ALL SCNS	5.37			4.49	82.85	83.90	84.32	86.352	82.9	0.05
499	ALL SCNS	5.37			4.16	82.93	83.94	84.22	85.919	82.1	0.06
500	ALL SCNS	5.37			3.82	82.91	83.90	84.09	85.832	83.2	0.07
501	ALL SCNS	5.37			3.48	82.96	83.95	84.01	85.776	84.1	0.08
502	ALL SCNS	5.37			3.82	83.05	83.90	84.03	85.736	84.0	0.08
503	ALL SCNS	5.37			4.19	82.91	83.80	83.95	85.719	84.5	0.06
504	ALL SCNS	5.37			4.50	82.84	83.75	83.94	85.788	83.1	0.05
505	ALL SCNS	5.37			4.87	83.25	84.13	84.51	86.498	82.9	0.04
506	ALL SCNS	5.37			5.21	82.95	85.42	86.88	89.799	82.3	0.02
507	ALL SCNS	5.37	5.37	5.38	5.38	82.84	90.03	98.16	97.949	-0.1	0.00
508	ALL SCNS	5.37	5.33	5.29	5.18	83.01	83.85	84.78	89.940	-0.1	0.01
509	ALL SCNS	5.37	5.34	5.30	5.20	82.90	83.42	83.85	87.133	-0.1	0.02
510	ALL SCNS	5.37	5.25	5.14	4.85	82.81	83.22	83.42	85.714	-0.1	0.03
511	ALL SCNS	5.37	5.16	4.97	4.49	82.83	83.20	83.35	85.276	-0.1	0.05
512	ALL SCNS	5.37	5.13	4.90	4.33	82.97	83.38	83.48	85.212	-0.1	0.05
513	ALL SCNS	5.37	5.10	4.82	4.17	82.82	83.27	83.27	85.025	-0.1	0.06
514	ALL SCNS	5.37	5.03	4.71	3.80	82.93	83.29	83.38	85.099	-0.1	0.07
515	ALL SCNS	5.36	4.93	4.65	3.46	82.94	83.32	83.34	85.125	-0.1	0.08
516	ALL SCNS	5.37	5.02	4.79	3.82	82.95	83.34	83.35	85.133	-0.1	0.07
517	ALL SCNS	5.37	5.11	4.88	4.19	82.91	83.30	83.35	85.068	-0.1	0.06
518	ALL SCNS	5.37	5.20	5.00	4.54	82.79	83.27	83.25	85.085	-0.1	0.05
519	ALL SCNS	5.37	5.27	5.15	4.88	82.88	83.30	83.46	85.233	-0.1	0.03
520	ALL SCNS	5.37	5.34	5.30	5.20	82.90	83.46	83.73	86.096	-0.1	0.02
521	ALL SCNS	5.37	5.38	5.38	5.38	82.85	86.02	90.63	94.136	-0.1	0.00
522	ALL SCNS	5.37			5.20	83.75	91.79	96.46	102.872	252.4	0.02
523	ALL SCNS	5.37			4.84	83.54	87.62	90.02	94.789	251.9	0.03
524	ALL SCNS	5.37			4.52	83.48	86.42	88.06	91.921	253.5	0.04
525	ALL SCNS	5.37			4.15	83.61	85.76	86.88	90.129	250.5	0.06
526	ALL SCNS	5.37			3.80	83.69	85.55	86.16	89.087	251.5	0.07
527	ALL SCNS	5.37			3.50	83.88	85.46	85.84	88.563	251.0	0.08
528	ALL SCNS	5.37			3.86	83.73	85.35	85.77	88.542	251.2	0.08

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 99.039 kPa

CONFIGURATION NO. 5 3 Brushes equally space: pos 1,3,5

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 2 (MPa)	AVG PRESS STATION 4 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 2 (K)	AVG TEMP STATION 4 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)
529	ALL SCNS	5.37			4.16	83.80	85.27	85.93	88.864	249.8	0.06
530	ALL SCNS	5.37			4.53	83.77	85.51	86.26	89.641	249.8	0.05
531	ALL SCNS	5.37			4.86	83.89	86.35	87.82	91.631	248.6	0.04
532	ALL SCNS	5.37			5.23	84.08	91.80	96.42	101.564	249.0	0.02
533	ALL SCNS	5.37	5.38	5.38	5.38	83.41	88.78	96.44	97.004	-0.1	0.00
534	ALL SCNS	5.37	5.33	5.29	5.19	83.30	83.85	84.45	87.710	-0.1	0.02
535	ALL SCNS	5.37	5.24	5.11	4.84	83.41	83.72	83.98	86.182	-0.1	0.03
536	ALL SCNS	5.37	5.14	4.94	4.48	83.63	83.88	84.01	85.970	-0.1	0.05
537	ALL SCNS	5.37	5.09	4.79	4.16	84.05	84.11	84.21	85.962	-0.1	0.05
538	ALL SCNS	5.35	5.01	4.77	3.82	84.95	84.81	85.11	86.719	-0.1	0.06
539	ALL SCNS	5.33	4.90	4.65	3.46	86.33	86.09	86.39	88.008	-0.1	0.08
540	ALL SCNS	5.33	4.98	4.77	3.80	87.30	87.03	87.40	88.834	-0.1	0.07
541	ALL SCNS	5.33	5.05	4.85	4.13	88.23	87.96	88.45	89.701	-0.1	0.06
542	ALL SCNS	5.35	5.17	4.94	4.49	90.10	89.80	90.20	91.400	-0.1	0.05
543	ALL SCNS	5.36	5.25	5.11	4.85	92.22	91.81	92.27	93.488	-0.1	0.04
544	ALL SCNS	5.37	5.34	5.30	5.20	94.36	94.00	94.61	96.258	-0.1	0.02
545	ALL SCNS	5.39	5.40	5.40	5.40	96.34	97.45	102.79	103.209	-0.1	0.00
546	ALL SCNS	5.41			5.23	85.23	101.07	109.69	127.461	420.7	0.02
547	ALL SCNS	5.41			4.89	84.94	93.48	97.87	114.849	416.9	0.03
548	ALL SCNS	5.40			4.55	84.74	90.72	94.03	108.360	416.2	0.04
549	ALL SCNS	5.40			4.20	84.48	88.67	90.91	102.913	419.0	0.06
550	ALL SCNS	5.40			3.85	84.35	88.20	90.11	101.140	420.8	0.07
551	ALL SCNS	5.40			3.50	84.40	87.97	89.73	99.923	419.2	0.08
552	ALL SCNS	5.40			3.84	84.50	88.34	90.33	100.826	421.4	0.07
553	ALL SCNS	5.40			4.20	84.49	88.26	90.29	100.757	419.6	0.07
554	ALL SCNS	5.40			4.54	84.64	88.85	91.30	103.000	420.6	0.05
555	ALL SCNS	5.40			4.89	84.89	90.82	94.21	108.317	423.1	0.04
556	ALL SCNS	5.40			5.23	85.25	99.78	107.31	124.034	412.8	0.02
557	ALL SCNS	5.39	5.39	5.40	5.39	82.31	86.24	92.34	98.770	-0.1	0.00
558	ALL SCNS	5.39	5.35	5.30	5.20	82.26	82.76	83.38	90.580	-0.1	0.01
559	ALL SCNS	5.39	5.26	5.11	4.85	82.13	82.57	82.88	88.964	-0.1	0.03
560	ALL SCNS	5.39	5.18	4.93	4.51	82.12	82.53	82.63	88.682	-0.1	0.04
561	ALL SCNS	5.39	5.11	4.74	4.16	82.03	82.47	82.58	88.365	-0.1	0.05
562	ALL SCNS	5.39	5.07	4.58	3.82	82.17	82.52	82.68	88.512	-0.1	0.06
563	ALL SCNS	5.39	5.01	4.41	3.47	82.22	82.53	82.68	88.645	-0.1	0.07
564	ALL SCNS	5.39	5.09	4.59	3.83	82.18	82.52	82.66	88.331	-0.1	0.06
565	ALL SCNS	5.39	5.15	4.76	4.17	82.24	82.47	82.63	88.369	-0.1	0.05
566	ALL SCNS	5.39	5.22	4.94	4.52	82.28	82.61	82.64	88.499	-0.1	0.04
567	ALL SCNS	5.39	5.29	5.13	4.87	82.15	82.51	82.58	88.451	-0.1	0.03
568	ALL SCNS	5.39	5.35	5.30	5.21	82.23	82.79	82.92	89.349	-0.1	0.02
569	ALL SCNS	5.39	5.39	5.40	5.29	82.14	85.43	90.62	96.859	-0.1	0.00
570	ALL SCNS	5.42			5.24	89.03	117.86	127.22	141.670	585.3	0.01
571	ALL SCNS	5.41			4.92	88.25	102.15	109.55	130.354	585.9	0.03
572	ALL SCNS	5.38			4.39	87.49	92.92	96.75	113.115	583.7	0.09
573	ALL SCNS	5.38			4.56	87.91	94.03	98.34	115.110	592.4	0.08
574	ALL SCNS	5.35			4.15	87.52	92.58	96.11	111.205	587.4	0.09
575	ALL SCNS	5.30			3.74	86.80	90.98	93.94	107.079	568.5	0.11
576	ALL SCNS	5.27			3.38	86.12	89.74	92.17	103.915	546.5	0.12
577	ALL SCNS	5.27			3.75	86.75	90.87	93.74	106.455	560.0	0.11
578	ALL SCNS	5.27			4.09	87.20	91.83	95.19	109.248	567.4	0.09
579	ALL SCNS	5.28			4.44	87.56	93.28	97.20	112.975	573.2	0.08
580	ALL SCNS	5.28			4.79	87.95	94.08	99.43	116.209	570.2	0.07
581	ALL SCNS	5.31			5.15	90.59	117.98	125.69	139.558	587.8	0.01
582	ALL SCNS	5.26	5.22	5.17	5.08	83.95	84.10	85.07	93.812	-0.1	0.02
583	ALL SCNS	5.24	5.10	4.93	4.69	83.73	83.67	84.16	90.992	-0.1	0.04
584	ALL SCNS	5.22	5.01	4.71	4.33	83.39	83.41	83.77	89.961	-0.1	0.05
585	ALL SCNS	5.21	4.92	4.52	3.98	83.32	83.29	83.62	89.520	-0.1	0.06
586	ALL SCNS	5.19	4.83	4.33	3.64	83.27	83.27	83.50	89.296	-0.1	0.07
587	ALL SCNS	5.16	4.73	4.14	3.26	83.09	83.17	83.47	89.219	-0.1	0.07
588	ALL SCNS	5.15	4.80	4.31	3.60	83.24	83.18	83.43	88.953	-0.1	0.07
589	ALL SCNS	5.14	4.86	4.48	3.94	83.31	83.24	83.52	88.975	-0.1	0.06
590	ALL SCNS	5.13	4.93	4.65	4.27	83.37	83.29	83.55	89.056	-0.1	0.05
591	ALL SCNS	5.13	5.00	4.84	4.61	83.37	83.34	83.60	89.240	-0.1	0.04
592	ALL SCNS	5.14	5.10	5.05	4.95	83.80	83.72	84.17	90.158	-0.1	0.01
593	ALL SCNS	5.15	5.15	5.16	5.15	84.17	85.98	90.45	96.138	-0.1	0.00

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 97.688 kPa

CONFIGURATION NO. 6 2 Brushes far apart - positions 2 & 5

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 3 (MPa)	AVG PRESS STATION 4 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 3 (K)	AVG TEMP STATION 4 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)
594	ALL SCNS	5.39	5.35	5.34	5.22	83.42	85.51	84.87	89.649	-0.1	0.02
595	ALL SCNS	5.39	5.26	5.25	4.87	82.93	84.06	83.67	86.664	-0.1	0.05
596	ALL SCNS	5.39	5.34	5.33	5.21	82.35	84.23	83.74	88.537	-0.1	0.03
597	ALL SCNS	5.39	5.24	5.24	4.86	82.44	83.42	82.99	86.028	-0.1	0.04
598	ALL SCNS	5.39	5.19	5.19	4.51	82.29	82.95	82.73	85.183	-0.1	0.06
599	ALL SCNS	5.38	5.19	5.18	4.17	82.09	82.79	82.54	84.731	-0.1	0.07
600	ALL SCNS	5.38	5.16	5.15	3.83	82.02	82.58	82.47	84.426	-0.1	0.08
601	ALL SCNS	5.38	5.13	5.12	3.49	82.27	82.65	82.54	84.596	-0.1	0.08
602	ALL SCNS	5.38	5.16	5.16	3.83	82.17	82.70	82.52	84.383	-0.1	0.08
603	ALL SCNS	5.38	5.21	5.20	4.18	82.08	82.53	82.34	84.195	-0.1	0.07
604	ALL SCNS	5.38	5.24	5.24	4.53	82.32	82.81	82.70	84.422	-0.1	0.06
605	ALL SCNS	5.39	5.25	5.25	4.88	82.26	82.87	82.73	84.625	-0.1	0.04
606	ALL SCNS	5.39	5.33	5.33	5.22	82.20	83.12	82.84	85.377	-0.1	0.02
607	ALL SCNS	5.39	5.40	5.39	5.39	82.21	85.34	85.29	91.947	-0.1	0.00
608	ALL SCNS	5.42	5.34	5.31	5.26	88.84	108.68	109.27	126.993	585.1	0.03
609	ALL SCNS	5.41	5.15	5.11	4.89	87.33	95.26	94.96	107.999	584.8	0.08
610	ALL SCNS	5.41	5.02	4.98	4.54	86.94	93.51	93.22	104.197	584.9	0.11
611	ALL SCNS	5.41	4.93	4.88	4.22	86.90	92.83	92.55	102.349	583.9	0.12
612	ALL SCNS	5.41	4.86	4.82	3.85	86.69	92.24	91.92	101.009	581.5	0.13
613	ALL SCNS	5.40	4.89	4.85	3.52	86.50	91.99	91.68	100.424	579.1	0.13
614	ALL SCNS	5.41	4.95	4.91	3.86	86.90	92.86	92.56	101.793	588.0	0.13
615	ALL SCNS	5.45	5.07	5.03	4.24	87.53	93.96	93.78	103.703	592.1	0.11
616	ALL SCNS	5.46	5.14	5.10	4.59	87.74	94.53	94.26	105.449	584.7	0.10
617	ALL SCNS	5.46	5.24	5.20	4.95	87.75	96.10	95.87	109.262	584.8	0.07
618	ALL SCNS	5.46	5.38	5.34	5.29	88.83	105.14	104.97	123.837	584.9	0.04
619	ALL SCNS	5.45	5.36	5.33	5.28	85.47	93.81	93.59	105.522	417.4	0.03
620	ALL SCNS	5.44	5.19	5.17	4.92	84.92	89.96	89.73	97.917	417.6	0.06
621	ALL SCNS	5.44	5.06	5.04	4.55	84.67	88.40	88.21	94.578	417.5	0.09
622	ALL SCNS	5.44	4.93	4.90	4.22	84.76	87.83	87.68	93.311	417.5	0.10
623	ALL SCNS	5.44	4.86	4.84	3.89	84.84	87.83	87.61	92.820	417.5	0.11
624	ALL SCNS	5.44	4.95	4.93	3.55	85.07	88.17	87.83	93.051	417.5	0.11
625	ALL SCNS	5.44	4.99	4.97	3.89	84.81	87.99	87.64	93.038	417.5	0.11
626	ALL SCNS	5.44	5.05	5.02	4.24	84.74	88.04	87.81	93.439	417.6	0.10
627	ALL SCNS	5.44	5.11	5.08	4.59	84.77	88.31	88.06	94.190	417.8	0.09
628	ALL SCNS	5.44	5.21	5.18	4.93	85.04	89.44	89.18	96.498	417.5	0.07
629	ALL SCNS	5.45	5.35	5.33	5.26	85.37	93.88	93.72	105.313	417.2	0.03
630	ALL SCNS	5.43	5.35	5.34	5.26	83.06	86.17	85.94	91.266	249.2	0.03
631	ALL SCNS	5.43	5.19	5.18	4.90	83.00	84.77	84.60	88.254	249.1	0.06
632	ALL SCNS	5.43	5.10	5.08	4.57	83.13	84.81	84.62	87.694	249.2	0.07
633	ALL SCNS	5.43	5.01	5.00	4.21	83.04	84.47	84.30	87.207	249.3	0.08
634	ALL SCNS	5.43	5.01	4.99	3.87	83.06	84.29	84.18	86.909	249.1	0.09
635	ALL SCNS	5.43	5.07	5.05	3.70	83.27	84.47	84.36	87.112	249.3	0.09
636	ALL SCNS	5.43	5.08	5.07	3.88	83.33	84.45	84.31	87.173	249.3	0.09
637	ALL SCNS	5.43	5.11	5.09	4.22	83.17	84.50	84.39	87.061	248.9	0.09
638	ALL SCNS	5.43	5.15	5.14	4.58	83.29	84.72	84.63	87.517	249.2	0.07
639	ALL SCNS	5.43	5.23	5.21	4.91	83.16	84.79	84.74	88.137	249.0	0.05
640	ALL SCNS	5.44	5.37	5.35	5.28	83.17	88.31	88.16	93.247	249.1	0.02
641	ALL SCNS	5.43	5.36	5.35	5.25	82.85	84.14	84.03	86.607	84.0	0.03
642	ALL SCNS	5.43	5.22	5.21	4.91	82.73	83.58	83.51	85.542	83.7	0.05
643	ALL SCNS	5.43	5.10	5.09	4.56	82.55	83.30	83.14	84.969	83.6	0.07
644	ALL SCNS	5.43	5.01	5.00	4.20	82.59	83.17	83.09	84.917	83.8	0.08
645	ALL SCNS	5.43	5.00	4.99	3.88	82.97	83.58	83.37	85.215	83.9	0.09
646	ALL SCNS	5.43	5.07	5.06	3.71	82.90	83.37	83.25	85.094	83.8	0.09
647	ALL SCNS	5.43	5.09	5.08	3.87	82.77	83.26	83.14	84.955	84.0	0.09
648	ALL SCNS	5.43	5.14	5.13	4.22	82.60	83.12	83.01	84.816	83.6	0.08
649	ALL SCNS	5.43	5.17	5.17	4.56	82.43	82.99	82.84	84.703	83.6	0.07
650	ALL SCNS	5.43	5.23	5.23	4.91	82.49	83.20	83.02	84.981	84.1	0.05
651	ALL SCNS	5.43	5.35	5.34	5.26	82.60	83.72	83.59	85.901	83.7	0.03
652	ALL SCNS	5.43	5.35	5.35	5.23	82.67	83.43	83.16	85.246	-0.2	0.03
653	ALL SCNS	5.43	5.22	5.22	4.89	82.84	83.45	83.13	84.902	-0.2	0.05
654	ALL SCNS	5.43	5.16	5.15	4.56	82.84	83.37	83.06	84.789	-0.1	0.06
655	ALL SCNS	5.43	5.13	5.12	4.22	83.45	83.89	83.60	85.241	-0.1	0.06
656	ALL SCNS	5.43	5.16	5.16	3.86	83.85	84.14	83.85	85.579	-0.1	0.07
657	ALL SCNS	5.43	5.21	5.21	4.22	83.53	83.96	83.64	85.415	-0.1	0.06
658	ALL SCNS	5.43	5.25	5.25	4.56	83.07	83.62	83.32	85.137	-0.1	0.05
659	ALL SCNS	5.43	5.27	5.27	4.91	83.38	83.98	83.60	85.432	-0.1	0.04
660	ALL SCNS	5.43	5.36	5.36	5.27	83.67	84.52	84.11	86.346	-0.1	0.02
661	ALL SCNS	5.43	5.44	5.44	5.44	83.58	89.63	90.36	94.244	-0.1	0.00

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 98.605 kPa

CONFIGURATION NO. 7 3 Brushes equally spaced - positions 1,3,5

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 2 (MPa)	AVG PRESS STATION 4 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 2 (K)	AVG TEMP STATION 4 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)
662	ALL SCNS	5.38	5.35	5.32	5.26	83.11	83.33	84.34	87.839	-0.1	0.02
663	ALL SCNS	5.38	5.27	5.14	4.89	83.36	83.63	83.91	86.372	-0.1	0.03
664	ALL SCNS	5.38	5.22	4.99	4.58	83.29	83.51	83.81	85.767	-0.1	0.04
665	ALL SCNS	5.38	5.15	4.82	4.21	83.17	83.39	83.63	85.493	-0.2	0.06
666	ALL SCNS	5.38	5.09	4.78	3.87	83.02	83.29	83.51	85.289	-0.1	0.07
667	ALL SCNS	5.37	5.05	4.74	3.67	83.06	83.24	83.47	85.233	-0.1	0.07
668	ALL SCNS	5.38	5.09	4.81	3.86	83.02	83.41	83.53	85.198	-0.1	0.07
669	ALL SCNS	5.38	5.17	4.88	4.22	83.13	83.34	83.60	85.276	-0.1	0.06
670	ALL SCNS	5.38	5.23	4.99	4.56	83.05	83.25	83.53	85.276	-0.1	0.05
671	ALL SCNS	5.38	5.30	5.17	4.93	83.00	83.33	83.51	85.558	-0.1	0.03
672	ALL SCNS	5.38	5.35	5.32	5.27	83.24	83.56	84.08	87.012	-0.1	0.01
673	ALL SCNS	5.38	5.38	5.39	5.42	83.43	84.72	87.49	95.111	-0.2	0.00
674	ALL SCNS	5.41	5.35	5.30	5.29	89.06	113.43	128.19	136.872	585.8	0.02
675	ALL SCNS	5.41	5.27	5.11	4.99	88.54	103.16	110.58	127.016	585.6	0.04
676	ALL SCNS	5.40	5.17	4.87	4.59	88.23	98.14	105.13	118.638	585.9	0.05
677	ALL SCNS	5.40	5.07	4.66	4.25	88.01	96.45	101.43	113.938	586.4	0.07
678	ALL SCNS	5.40	4.96	4.43	3.88	87.85	94.98	98.86	109.740	583.9	0.08
679	ALL SCNS	5.40	4.91	4.36	3.71	87.87	94.70	98.60	108.778	584.5	0.09
680	ALL SCNS	5.40	4.87	4.31	3.54	87.79	94.40	97.91	108.011	584.8	0.09
681	ALL SCNS	5.40	4.97	4.47	3.90	88.16	95.91	99.94	111.113	596.8	0.08
682	ALL SCNS	5.40	5.06	4.65	4.25	88.03	95.90	100.28	112.219	585.8	0.07
683	ALL SCNS	5.40	5.15	4.84	4.58	88.29	97.26	102.88	115.653	585.5	0.06
684	ALL SCNS	5.40	5.22	5.05	4.92	88.49	100.03	107.36	121.918	585.5	0.04
685	ALL SCNS	5.41	5.33	5.28	5.27	89.08	111.10	121.23	134.032	585.5	0.02
686	ALL SCNS	5.39	5.33	5.27	5.24	85.88	96.78	102.65	117.678	417.7	0.02
687	ALL SCNS	5.39	5.25	5.08	4.91	85.58	92.69	95.78	107.088	417.9	0.03
688	ALL SCNS	5.39	5.16	4.88	4.56	85.42	91.18	93.48	102.681	417.6	0.05
689	ALL SCNS	5.38	5.08	4.67	4.21	85.36	90.08	92.08	99.741	417.7	0.06
690	ALL SCNS	5.39	4.99	4.49	3.87	85.05	89.22	90.96	97.441	417.7	0.07
691	ALL SCNS	5.38	4.88	4.38	3.50	85.14	88.97	90.44	96.279	417.9	0.08
692	ALL SCNS	5.38	4.99	4.50	3.87	85.23	89.42	91.10	97.279	417.7	0.07
693	ALL SCNS	5.38	5.08	4.67	4.23	85.29	89.71	91.75	98.588	417.8	0.06
694	ALL SCNS	5.38	5.15	4.85	4.55	85.45	90.29	92.54	100.354	417.4	0.05
695	ALL SCNS	5.39	5.23	5.06	4.90	85.95	91.89	94.72	104.443	417.9	0.04
696	ALL SCNS	5.39	5.33	5.27	5.25	86.33	98.04	103.76	117.342	418.4	0.02
697	ALL SCNS	5.38	5.34	5.29	5.25	84.11	90.03	92.87	99.938	248.8	0.02
698	ALL SCNS	5.37	5.27	5.12	4.90	83.84	87.35	88.71	94.095	248.8	0.03
699	ALL SCNS	5.37	5.19	4.95	4.55	83.70	86.46	87.26	91.581	248.7	0.05
700	ALL SCNS	5.37	5.11	4.72	4.19	83.70	85.59	86.41	89.806	248.3	0.06
701	ALL SCNS	5.37	5.02	4.57	3.84	83.82	85.35	86.05	89.098	248.5	0.07
702	ALL SCNS	5.37	4.90	4.41	3.49	83.64	85.24	85.76	88.562	249.6	0.08
703	ALL SCNS	5.37	5.00	4.50	3.84	83.67	85.11	85.74	88.600	248.8	0.07
704	ALL SCNS	5.37	5.09	4.67	4.18	83.70	85.17	85.97	88.944	248.8	0.06
705	ALL SCNS	5.37	5.16	4.89	4.54	83.84	85.39	86.13	89.514	249.1	0.05
706	ALL SCNS	5.37	5.24	5.09	4.89	83.82	85.71	86.78	90.700	248.9	0.04
707	ALL SCNS	5.37	5.33	5.28	5.24	84.03	89.83	92.35	97.942	249.1	0.02
708	ALL SCNS	5.37	5.34	5.29	5.23	83.33	84.78	85.57	88.415	84.0	0.02
709	ALL SCNS	5.37	5.26	5.10	4.87	83.44	84.32	84.75	87.124	84.4	0.04
710	ALL SCNS	5.37	5.19	4.93	4.53	83.28	84.04	84.41	86.493	84.2	0.05
711	ALL SCNS	5.37	5.12	4.75	4.18	83.36	84.02	84.34	86.281	84.1	0.05
712	ALL SCNS	5.36	5.02	4.58	3.85	83.84	84.35	84.61	86.485	84.1	0.06
713	ALL SCNS	5.34	4.88	4.43	3.45	83.70	84.38	84.53	86.372	84.2	0.07
714	ALL SCNS	5.33	4.97	4.56	3.82	83.93	84.52	84.69	86.796	84.2	0.09
715	ALL SCNS	5.33	5.07	4.69	4.18	83.98	84.46	84.68	86.657	83.9	0.07
716	ALL SCNS	5.33	5.14	4.85	4.47	84.04	84.42	84.77	86.869	83.4	0.07
717	ALL SCNS	5.34	5.22	5.06	4.85	84.42	84.87	85.24	87.499	84.0	0.04
718	ALL SCNS	5.35	5.32	5.28	5.22	84.71	86.11	86.84	89.394	83.8	0.03
719	ALL SCNS	5.34	5.30	5.23	5.14	85.31	84.76	85.58	87.998	-0.1	0.04
720	ALL SCNS	5.32	5.21	5.05	4.80	85.18	84.70	85.41	87.201	-0.1	0.05
721	ALL SCNS	5.30	5.13	4.87	4.48	84.99	84.66	85.28	86.947	-0.1	0.06
722	ALL SCNS	5.17	4.92	4.55	3.96	83.55	83.70	84.00	85.814	-0.1	0.06
723	ALL SCNS	5.16	4.84	4.47	3.65	83.59	83.85	84.13	85.861	-0.1	0.07
724	ALL SCNS	5.16	4.79	4.46	3.45	83.77	84.01	84.17	86.065	-0.1	0.07
725	ALL SCNS	5.16	4.83	4.53	3.64	83.83	84.06	84.25	86.173	-0.1	0.06
726	ALL SCNS	5.16	4.93	4.58	4.00	83.96	84.26	84.38	86.203	-0.1	0.05
727	ALL SCNS	5.16	5.00	4.74	4.33	83.92	84.13	84.34	86.264	-0.1	0.04
728	ALL SCNS	5.16	5.06	4.90	4.67	83.84	84.21	84.32	86.286	-0.1	0.03
729	ALL SCNS	5.17	5.13	5.09	5.02	84.08	84.39	84.70	87.097	-0.1	0.02
730	ALL SCNS	5.17	5.17	5.18	5.21	84.54	85.93	89.34	96.594	-0.1	0.00

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 97.653 kPa

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG	SCAN	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)
740	1	5.45	5.25	83.99	86.05	-0.2	0.044	0.20
740	2	5.42	5.12	83.80	85.97	-0.2	0.062	0.30
740	3	5.41	5.04	83.66	85.71	-0.2	0.074	0.37
740	4	5.42	5.00	83.79	85.66	-0.2	0.071	0.41
740	5	5.41	5.02	83.73	85.57	-0.2	0.070	0.39
740	6	5.42	5.06	83.80	85.57	-0.2	0.064	0.36
740	7	5.42	5.06	83.83	85.62	-0.2	0.070	0.36
740	8	5.40	4.92	83.70	85.75	-0.2	0.085	0.48
740	9	5.39	4.81	83.93	85.62	-0.2	0.098	0.58
740	10	5.38	4.74	83.83	85.44	-0.2	0.094	0.64
740	11	5.38	4.73	83.76	85.40	-0.2	0.094	0.65
740	12	5.39	4.72	83.86	85.53	-0.2	0.095	0.66
740	13	5.39	4.73	83.76	85.49	-0.1	0.093	0.66
740	14	5.38	4.75	83.70	85.31	-0.2	0.090	0.64
740	15	5.39	4.80	83.73	85.53	-0.1	0.088	0.59
740	16	5.39	4.78	83.76	85.31	-0.1	0.096	0.61
740	17	5.38	4.72	83.70	85.40	-0.1	0.097	0.67
740	18	5.38	4.67	83.63	85.44	-0.2	0.100	0.71
740	19	5.38	4.62	83.60	85.53	-0.2	0.102	0.75
740	20	5.37	4.61	83.73	85.23	-0.1	0.101	0.76
740	21	5.37	4.61	83.66	85.49	-0.1	0.101	0.76
740	22	5.37	4.55	83.47	85.62	-0.2	0.107	0.82
740	23	5.37	4.59	83.44	85.62	-0.1	0.101	0.78
740	24	5.36	4.53	83.66	85.40	-0.1	0.109	0.84
740	25	5.36	4.50	83.47	85.36	-0.1	0.111	0.87
740	26	5.35	4.36	83.63	85.49	-0.2	0.118	0.99
740	27	5.34	4.31	83.70	85.57	-0.1	0.126	1.04
740	28	5.34	4.32	83.73	85.31	-0.1	0.123	1.02
740	29	5.34	4.27	83.60	85.53	-0.1	0.131	1.08
740	30	5.34	4.27	83.53	85.53	-0.1	0.123	1.06
740	31	5.34	4.28	83.50	85.62	-0.2	0.127	1.06
740	32	5.34	4.30	83.73	85.45	-0.2	0.126	1.04
740	33	5.34	4.26	83.40	85.23	-0.1	0.125	1.09
740	34	5.33	4.18	83.50	85.27	-0.2	0.129	1.15
740	35	5.33	4.14	83.50	85.53	-0.1	0.133	1.19
740	36	5.32	4.07	83.44	85.18	-0.1	0.135	1.25
740	37	5.32	4.05	83.63	85.31	-0.2	0.136	1.27
740	38	5.33	4.07	83.40	85.53	-0.2	0.133	1.25
740	39	5.32	4.07	83.60	85.36	-0.2	0.135	1.25
740	40	5.33	4.08	83.50	85.31	-0.1	0.134	1.25
740	41	5.33	4.00	83.34	85.14	-0.1	0.142	1.32
740	42	5.31	3.94	83.40	85.40	-0.2	0.142	1.37
740	43	5.31	3.89	83.53	85.53	-0.1	0.145	1.41
740	44	5.30	3.80	83.50	85.27	-0.2	0.153	1.51
740	45	5.30	3.77	83.40	85.49	-0.1	0.150	1.53
740	46	5.30	3.76	83.47	85.49	-0.1	0.149	1.54
740	47	5.31	3.78	83.34	85.27	-0.1	0.154	1.53
740	48	5.30	3.80	83.47	85.36	-0.2	0.152	1.50
740	49	5.31	3.78	83.17	85.27	-0.2	0.160	1.53
740	50	5.30	3.69	83.34	85.27	-0.1	0.160	1.61
740	51	5.30	3.63	83.27	85.14	-0.1	0.155	1.66
740	52	5.28	3.50	83.44	85.31	-0.1	0.158	1.78
740	53	5.28	3.51	83.40	85.31	-0.1	0.163	1.77
740	54	5.28	3.53	83.27	85.10	-0.1	0.156	1.76

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 97.653 kPa

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG	SCAN	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)
740	55	5.28	3.55	83.27	85.10	-0.2	0.157	1.73
740	56	5.29	3.59	83.27	85.23	-0.1	0.167	1.70
740	57	5.29	3.54	83.21	85.23	-0.1	0.169	1.75
740	58	5.28	3.45	83.30	85.18	-0.1	0.173	1.82
740	59	5.28	3.43	83.37	85.18	-0.1	0.169	1.85
740	60	5.28	3.36	83.30	85.31	-0.1	0.163	1.91
740	61	5.28	3.35	83.14	85.23	-0.1	0.166	1.92
740	62	5.28	3.36	83.34	85.40	-0.1	0.164	1.92
740	63	5.28	3.39	83.17	85.40	-0.1	0.162	1.89
740	64	5.28	3.41	83.27	85.18	-0.1	0.154	1.86
740	65	5.27	3.46	83.21	85.27	-0.1	0.154	1.81
740	66	5.27	3.41	83.21	85.44	-0.1	0.163	1.86
740	67	5.27	3.37	83.37	85.27	-0.1	0.169	1.90
740	68	5.28	3.37	83.14	85.31	-0.2	0.169	1.91
740	69	5.27	3.31	83.24	85.18	-0.1	0.166	1.96
740	70	5.27	3.28	83.34	85.10	-0.1	0.167	1.99
740	71	5.27	3.33	83.27	85.36	-0.1	0.165	1.94
740	72	5.27	3.31	83.40	85.23	-0.1	0.166	1.95
740	73	5.27	3.33	83.27	85.31	-0.1	0.164	1.93
740	74	5.27	3.31	83.01	85.31	-0.1	0.170	1.96
740	75	5.26	3.24	83.37	85.36	-0.1	0.170	2.03
740	76	5.25	3.16	83.27	85.27	-0.1	0.171	2.10
740	77	5.25	3.15	83.37	85.53	-0.1	0.171	2.10
740	78	5.25	3.14	83.44	85.44	-0.1	0.171	2.11
740	79	5.26	3.15	83.34	85.31	-0.1	0.170	2.10
740	80	5.26	3.17	83.14	85.27	-0.1	0.176	2.09
740	81	5.26	3.25	83.37	85.36	-0.1	0.171	2.01
740	82	5.27	3.29	83.47	85.44	-0.2	0.172	1.98
740	83	5.26	3.20	83.47	85.49	-0.2	0.167	2.06
740	84	5.25	3.12	83.34	85.40	-0.2	0.169	2.13
740	85	5.25	3.05	83.44	85.31	-0.1	0.177	2.19
740	86	5.24	3.00	83.40	85.36	-0.1	0.176	2.25
740	87	5.24	2.92	83.30	85.49	-0.1	0.178	2.32
740	88	5.24	2.93	83.30	85.49	-0.1	0.176	2.31
740	89	5.24	2.97	83.14	85.62	-0.2	0.173	2.27
740	90	5.24	3.03	83.24	85.36	-0.1	0.174	2.21
740	91	5.25	3.06	83.21	85.36	-0.1	0.175	2.19
740	92	5.24	2.89	83.27	85.40	-0.2	0.181	2.35
740	93	5.24	2.88	83.24	85.27	-0.1	0.180	2.36
740	94	5.23	2.83	83.34	85.40	-0.2	0.178	2.41
740	95	5.23	2.83	83.37	85.36	-0.1	0.180	2.41
740	96	5.24	2.82	83.24	85.31	-0.1	0.179	2.42
740	97	5.23	2.83	83.17	85.40	-0.1	0.179	2.41
740	98	5.24	2.83	83.17	85.36	-0.1	0.179	2.40
740	99	5.23	2.85	83.17	85.40	-0.1	0.177	2.38
740	100	5.23	2.86	83.17	85.36	-0.1	0.184	2.37
740	101	5.23	2.75	83.11	85.27	-0.1	0.182	2.47
740	102	5.22	2.66	83.30	85.44	-0.1	0.186	2.56
740	103	5.22	2.65	83.14	85.44	-0.1	0.189	2.57
740	104	5.22	2.63	83.24	85.44	-0.2	0.178	2.59
740	105	5.21	2.54	83.24	85.49	-0.2	0.176	2.67
740	106	5.22	2.58	83.17	85.31	-0.1	0.192	2.63
740	107	5.22	2.63	83.14	85.36	-0.2	0.186	2.59
740	108	5.22	2.62	83.17	85.44	-0.1	0.191	2.60
740	109	5.22	2.46	83.21	85.31	-0.2	0.197	2.75

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 97.653 kPa

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG SCAN	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)
740 110	5.21	2.31	83.21	85.44	-0.1	0.185	2.90
740 111	5.21	2.33	83.21	85.36	-0.1	0.195	2.88
740 112	5.21	2.36	83.27	85.44	-0.2	0.190	2.85
740 113	5.20	2.31	83.21	85.44	-0.1	0.188	2.90
740 114	5.21	2.37	83.08	85.44	-0.2	0.189	2.84
740 115	5.21	2.36	83.07	85.44	-0.2	0.188	2.84
740 116	5.21	2.44	83.24	85.44	-0.1	0.192	2.77
740 117	5.20	2.18	83.01	85.44	-0.1	0.196	3.02
740 118	5.19	2.07	83.17	85.53	-0.1	0.199	3.12
740 119	5.19	2.05	83.14	85.53	-0.2	0.193	3.14
740 120	5.19	2.01	83.17	85.62	-0.1	0.194	3.18
740 121	5.19	2.04	83.11	85.45	-0.1	0.195	3.15
740 122	5.19	2.03	83.17	85.44	-0.2	0.195	3.16
740 123	5.19	2.07	83.17	85.53	-0.2	0.193	3.12
740 124	5.19	2.11	83.08	85.45	-0.2	0.194	3.09
740 125	5.19	2.11	83.27	85.40	-0.1	0.200	3.08
740 126	5.19	1.95	83.14	85.36	-0.2	0.196	3.23
740 127	5.19	1.93	83.14	85.70	-0.1	0.200	3.26
740 128	5.18	1.87	83.08	85.62	-0.1	0.196	3.31
740 129	5.18	1.88	83.14	85.05	-0.2	0.202	3.30
740 130	5.18	1.83	83.08	85.53	-0.1	0.196	3.35
740 131	5.18	1.82	83.21	85.27	-0.1	0.202	3.36
740 132	5.18	1.83	83.17	85.27	-0.1	0.195	3.35
740 133	5.18	1.88	83.08	85.49	-0.1	0.199	3.30
740 134	5.18	1.81	83.21	85.45	-0.2	0.207	3.36
740 135	5.17	1.71	83.14	85.36	-0.2	0.194	3.45
740 136	5.17	1.67	83.17	85.70	-0.2	0.203	3.50
740 137	5.17	1.67	83.24	85.57	-0.2	0.200	3.50
740 138	5.17	1.65	83.27	85.57	-0.1	0.201	3.51
740 139	5.17	1.66	83.14	85.70	-0.2	0.201	3.51
740 140	5.16	1.67	83.04	85.23	-0.1	0.200	3.49
740 141	5.17	1.72	83.14	85.44	-0.1	0.200	3.45
740 142	5.17	1.77	63.21	84.84	-0.1	0.199	3.41
740 143	5.17	1.74	83.30	85.18	-0.1	0.205	3.42
740 144	5.17	1.69	83.17	85.57	-0.1	0.200	3.47
740 145	5.17	1.67	83.14	85.36	-0.2	0.203	3.50
740 146	5.17	1.64	83.24	85.23	-0.2	0.202	3.52
740 147	5.16	1.63	83.17	85.49	-0.2	0.200	3.53
740 148	5.16	1.64	83.11	85.45	-0.1	0.201	3.53
740 149	5.17	1.66	83.14	85.06	-0.1	0.200	3.50
740 150	5.16	1.70	83.27	85.19	-0.2	0.198	3.46
740 151	5.17	1.76	83.08	85.40	-0.1	0.199	3.41
740 152	5.17	1.75	83.14	85.31	-0.1	0.203	3.42
740 153	5.16	1.68	83.14	85.10	-0.1	0.200	3.48
740 154	5.16	1.67	83.04	85.36	-0.2	0.200	3.49
740 155	5.17	1.65	83.14	85.62	-0.1	0.202	3.52
740 156	5.16	1.63	83.11	85.31	-0.1	0.201	3.53
740 157	5.16	1.64	83.17	85.45	-0.1	0.200	3.53
740 158	5.16	1.64	83.11	85.31	-0.2	0.201	3.52
740 159	5.16	1.70	83.17	85.36	-0.2	0.198	3.47
740 160	5.16	1.73	83.21	85.44	-0.2	0.199	3.43
740 161	5.17	1.76	83.24	85.36	-0.2	0.202	3.41
740 162	5.16	1.71	83.24	85.49	-0.1	0.200	3.45
740 163	5.17	1.68	83.31	85.53	-0.1	0.201	3.48
740 164	5.16	1.65	83.24	84.93	-0.2	0.201	3.51

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 97.653 kPa

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG SCAN	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)
740 165	5.16	1.63	83.31	85.53	-0.1	0.200	3.53
740 166	5.16	1.63	83.17	85.49	-0.1	0.199	3.53
740 167	5.16	1.64	83.27	85.62	-0.2	0.200	3.51
740 168	5.17	1.65	83.24	85.75	-0.1	0.198	3.51
740 169	5.17	1.72	83.27	85.70	-0.1	0.198	3.44
740 170	5.16	1.76	83.34	85.62	-0.1	0.199	3.41
740 171	5.16	1.71	83.17	85.70	-0.2	0.201	3.45
740 172	5.16	1.67	83.14	85.62	-0.2	0.200	3.49
740 173	5.16	1.66	83.24	85.49	-0.1	0.200	3.50
740 174	5.16	1.63	83.21	85.53	-0.1	0.200	3.53
740 175	5.16	1.63	83.14	85.57	-0.2	0.199	3.53
740 176	5.16	1.63	83.30	85.83	-0.1	0.200	3.52
740 177	5.16	1.67	83.17	85.49	-0.1	0.198	3.49
740 178	5.16	1.71	83.21	85.79	-0.2	0.197	3.45
740 179	5.16	1.76	83.21	85.79	-0.1	0.198	3.40
740 180	5.16	1.70	83.17	85.66	-0.1	0.201	3.46
740 181	5.16	1.68	83.27	85.75	-0.1	0.199	3.48
740 182	5.16	1.64	83.24	85.96	-0.1	0.200	3.52
740 183	5.16	1.63	83.27	85.79	-0.1	0.199	3.53
740 184	5.16	1.63	83.30	85.83	-0.2	0.200	3.53
740 185	5.15	1.57	83.27	85.83	-0.1	0.201	3.58
740 186	5.15	1.58	83.27	85.62	-0.2	0.200	3.58
740 187	5.16	1.61	83.11	85.62	-0.1	0.197	3.55
740 188	5.16	1.67	83.37	85.75	-0.2	0.199	3.49
740 189	5.16	1.61	83.44	85.92	-0.1	0.202	3.54
740 190	5.15	1.52	83.34	85.88	-0.1	0.203	3.63
740 191	5.15	1.50	83.53	86.09	-0.2	0.200	3.65
740 192	5.15	1.49	83.30	85.83	-0.1	0.202	3.66
740 193	5.15	1.46	83.37	85.70	-0.1	0.200	3.69
740 194	5.14	1.46	83.47	85.88	-0.2	0.202	3.68
740 195	5.15	1.46	83.37	85.92	-0.2	0.200	3.69
740 196	5.15	1.51	83.37	85.75	-0.1	0.199	3.64
740 197	5.15	1.55	83.50	85.66	-0.2	0.200	3.59
740 198	5.15	1.54	83.44	85.92	-0.2	0.205	3.61
740 199	5.15	1.44	83.50	85.92	-0.2	0.202	3.71
740 200	5.14	1.41	83.67	86.05	-0.2	0.201	3.73
740 201	5.14	1.36	83.40	85.71	-0.2	0.203	3.78
740 202	5.14	1.34	83.40	85.83	-0.2	0.201	3.80
740 203	5.14	1.31	83.37	85.96	-0.2	0.205	3.83
740 204	5.14	1.29	83.27	85.92	-0.2	0.201	3.84
740 205	5.14	1.34	83.47	85.75	-0.1	0.202	3.79
740 206	5.14	1.34	83.50	85.92	-0.1	0.203	3.80
740 207	5.14	1.27	83.57	86.14	-0.2	0.206	3.86
740 208	5.13	1.23	83.44	85.96	-0.2	0.203	3.91
740 209	5.13	1.21	83.34	85.88	-0.2	0.206	3.92
740 210	5.13	1.17	83.57	85.96	-0.2	0.206	3.96
740 211	5.13	1.10	83.53	85.83	-0.1	0.206	4.03
740 212	5.13	1.09	83.57	86.01	-0.2	0.205	4.04
740 213	5.13	1.08	83.63	86.09	-0.1	0.206	4.05
740 214	5.13	1.10	83.50	85.97	-0.2	0.202	4.03
740 215	5.13	1.15	83.37	86.05	-0.1	0.205	3.98
740 216	5.13	1.11	83.44	85.96	-0.2	0.206	4.02
740 217	5.12	1.04	83.47	85.96	-0.2	0.205	4.08
740 218	5.12	1.04	83.50	86.09	-0.1	0.206	4.09
740 219	5.12	0.96	83.40	85.83	-0.2	0.206	4.16

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 97.653 kPa

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG SCAN	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)
740 220	5.12	0.95	83.53	86.31	-0.1	0.206	4.17
740 221	5.12	0.96	83.44	86.01	-0.2	0.206	4.16
740 222	5.12	0.96	83.60	86.05	-0.2	0.206	4.16
740 223	5.12	0.99	83.47	86.01	-0.2	0.203	4.13
740 224	5.12	1.04	83.57	85.83	-0.2	0.206	4.08
740 225	5.12	1.04	83.57	86.01	-0.1	0.206	4.08
740 226	5.12	0.99	83.40	85.84	-0.2	0.206	4.13
740 227	5.12	0.97	83.57	86.09	-0.1	0.206	4.15
740 228	5.12	0.95	83.40	85.83	-0.1	0.206	4.17
740 229	5.11	0.87	83.44	86.01	-0.1	0.206	4.25
740 230	5.11	0.82	83.50	86.09	-0.1	0.206	4.29
740 231	5.11	0.83	83.53	85.88	-0.1	0.206	4.29
740 232	5.11	0.86	83.50	85.62	-0.1	0.205	4.25
740 233	5.12	0.87	83.37	85.06	-0.1	0.206	4.25
740 234	5.11	0.81	83.53	85.84	-0.1	0.206	4.30
740 235	5.11	0.78	83.50	85.79	-0.1	0.206	4.32
740 236	5.11	0.74	83.47	85.75	-0.2	0.206	4.37
740 237	5.11	0.69	83.47	85.92	-0.1	0.206	4.41
740 238	5.10	0.68	83.44	85.75	-0.1	0.206	4.42
740 239	5.11	0.68	83.44	85.66	-0.1	0.206	4.43
740 240	5.10	0.68	83.44	85.79	-0.1	0.206	4.43
740 241	5.10	0.70	83.40	85.97	-0.1	0.206	4.41
740 242	5.10	0.73	83.44	85.79	-0.2	0.206	4.38
740 243	5.10	0.70	83.44	85.71	-0.1	0.206	4.41
740 244	5.10	0.65	83.30	85.66	-0.1	0.206	4.45
740 245	5.10	0.61	83.34	86.01	-0.2	0.206	4.50
740 246	5.10	0.59	83.50	85.79	-0.2	0.206	4.52
740 247	5.10	0.58	83.44	85.79	-0.1	0.206	4.52
740 248	5.10	0.57	83.50	85.79	-0.2	0.206	4.53
740 249	5.10	0.58	83.50	85.71	-0.2	0.206	4.52
740 250	5.10	0.57	83.37	85.79	-0.1	0.206	4.53
740 251	5.10	0.57	83.50	85.70	-0.2	0.206	4.53
740 252	5.10	0.55	83.34	85.84	-0.2	0.206	4.54
740 253	5.10	0.51	83.37	85.75	-0.2	0.206	4.58
740 254	5.09	0.49	83.50	85.79	-0.2	0.206	4.60
740 255	5.09	0.48	83.44	85.66	-0.2	0.206	4.61
740 256	5.09	0.48	83.44	85.88	-0.2	0.206	4.62
740 257	5.10	0.48	83.34	85.79	-0.2	0.206	4.62
740 258	5.09	0.48	83.30	85.79	-0.1	0.206	4.61
740 259	5.09	0.48	83.24	85.49	-0.1		4.61
740 260	5.09	0.48	83.47	85.79	-0.1		4.62
740 261	5.09	0.48	83.37	85.88	-0.2		4.62
740 262	5.09	0.48	83.24	85.62	-0.1		4.62
740 263	5.10	0.48	83.37	85.79	-0.2		4.62
740 264	5.09	0.48	83.57	85.84	-0.1		4.61
740 265	5.09	0.48	83.47	85.88	-0.2		4.61
740 266	5.09	0.48	83.24	85.84	-0.1		4.61
740 267	5.10	0.48	83.30	85.88	-0.2		4.62
740 268	5.09	0.47	83.21	85.71	-0.1		4.62
740 269	5.09	0.48	83.37	85.62	-0.2		4.61
740 270	5.09	0.47	83.40	85.62	-0.2		4.61
740 271	5.09	0.48	83.40	85.79	-0.2		4.62
740 272	5.09	0.48	83.44	85.92	-0.2		4.62
740 273	5.09	0.47	83.44	85.75	-0.1		4.62
740 274	5.09	0.47	83.37	85.84	-0.2		4.62

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 97.653 kPa

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG	SCAN	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	AVERAGE LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)
740	275	5.09	0.48	83.30	85.70	-0.1		4.61
740	276	5.09	0.48	83.27	85.83	-0.2		4.62
740	277	5.09	0.48	83.34	85.83	-0.2		4.62
740	278	5.09	0.47	83.21	85.88	-0.2		4.62
740	279	5.09	0.48	83.37	85.88	-0.2		4.61
740	280	5.09	0.47	83.34	85.71	-0.1		4.62
740	281	5.09	0.47	83.24	86.14	-0.1		4.61
740	282	5.09	0.48	83.60	85.71	-0.2	0.206	4.61
740	283	5.09	0.47	83.30	85.83	-0.2	0.206	4.62
740	284	5.09	0.47	83.44	86.05	-0.2	0.206	4.61
740	285	5.09	0.48	83.50	85.96	-0.2	0.206	4.61
740	286	5.09	0.47	83.50	85.84	-0.1	0.206	4.61
740	287	5.09	0.53	83.47	85.79	-0.2	0.193	4.56
740	288	5.10	0.77	83.47	85.75	-0.1	0.204	4.33
740	289	5.10	0.84	83.34	85.71	-0.1	0.201	4.26
740	290	5.11	1.09	83.44	86.09	-0.2	0.201	4.02
740	291	5.12	1.28	83.34	85.96	-0.2	0.186	3.84
740	292	5.13	1.59	83.40	85.88	-0.2	0.194	3.54
740	293	5.14	1.73	83.44	85.70	-0.2	0.193	3.41
740	294	5.15	2.01	83.53	85.79	-0.1	0.193	3.13
740	295	5.16	2.27	83.57	85.70	-0.1	0.178	2.89
740	296	5.16	2.28	83.50	85.88	-0.2	0.183	2.87
740	297	5.17	2.44	83.57	85.79	-0.2	0.177	2.73
740	298	5.17	2.52	83.53	85.83	-0.1	0.179	2.65
740	299	5.17	2.65	83.53	85.83	-0.2	0.173	2.53
740	300	5.18	2.65	83.40	85.70	-0.2	0.175	2.53
740	301	5.18	2.71	83.70	85.79	-0.1	0.171	2.47
740	302	5.19	2.91	83.63	85.88	-0.1	0.146	2.28
740	303	5.20	3.10	83.47	85.79	-0.1	0.161	2.10
740	304	5.20	3.08	83.57	85.70	-0.2	0.161	2.11
740	305	5.20	3.17	83.67	85.62	-0.1	0.160	2.03
740	306	5.20	3.15	83.60	85.53	-0.1	0.161	2.05
740	307	5.19	3.23	83.90	85.83	-0.2	0.149	1.97
740	308	5.20	3.27	83.83	85.83	-0.1	0.158	1.93
740	309	5.21	3.41	83.76	85.75	-0.1	0.144	1.80
740	310	5.22	3.51	83.80	85.66	-0.2	0.147	1.71
740	311	5.23	3.83	83.83	85.62	-0.1	0.138	1.40
740	312	5.24	4.03	83.80	85.53	-0.2	0.124	1.21
740	313	5.25	4.19	83.76	85.79	-0.2	0.099	1.06
740	314	5.25	4.20	83.83	85.75	-0.1	0.119	1.06
740	315	5.26	4.40	83.99	85.66	-0.2	0.106	0.86
740	316	5.27	4.52	83.83	85.70	-0.2	0.096	0.74
740	317	5.27	4.56	83.96	85.57	-0.1	0.097	0.71
740	318	5.29	4.70	83.96	85.57	-0.1	0.087	0.58
740	319	5.29	4.70	83.96	85.36	-0.2	0.087	0.59
740	320	5.33	5.13	83.83	86.10	-0.2	0.055	0.21
740	321	5.33	5.14	84.12	85.71	-0.2	0.043	0.19
740	322	5.34	5.20	84.16	85.79	-0.1	0.031	0.14
740	323	5.34	5.23	84.25	85.79	-0.1	0.020	0.11
740	324	5.35	5.27	84.22	86.09	-0.1	0.015	0.09
740	325	5.35	5.28	84.48	86.10	-0.2	0.014	0.08
740	326	5.36	5.29	84.45	86.05	-0.2	0.014	0.07
740	327	5.35	5.28	84.32	86.36	-0.2	0.013	0.07
740	328	5.36	5.29	84.55	86.22	-0.2	0.013	0.07
740	329	5.36	5.30	84.45	86.14	-0.2	0.012	0.06
740	330	5.36	5.30	84.55	86.53	-0.2	0.012	0.06
740	331	5.36	5.30	84.71	86.44	-0.1	0.012	0.06
740	332	5.36	5.31	84.64	86.53	-0.1	0.011	0.05
740	333	5.36	5.31	84.55	86.49	-0.2	0.011	0.05

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 98.363 kPa

CONFIGURATION NO. 9 Single brush in position 1 with stubby rotor

FLUID: HYDROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 2 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 2 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	VENTURI 2 LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)	DELTA-P STA 1-2 (MPd)
805	ALL SCNS	3.04	2.50	2.51	26.97	29.67	31.91	1094.9	0.059	0.53	0.54
806	ALL SCNS	2.98	2.28	2.29	26.65	29.17	31.49	1092.1	0.068	0.69	0.70
807	ALL SCNS	2.92	2.07	2.08	26.51	29.02	31.28	1094.2	0.074	0.84	0.86
808	ALL SCNS	2.85	1.76	1.78	26.30	28.64	30.96	1094.4	0.077	1.07	1.08
809	ALL SCNS	2.81	1.60	1.61	26.26	28.64	30.89	1097.6	0.000	1.19	1.21
810	ALL SCNS	2.82	1.75	1.76	26.34	28.68	30.84	1098.1	0.000	1.06	1.08
811	ALL SCNS	2.84	1.97	1.98	26.49	28.81	31.06	1087.8	0.000	0.86	0.87
812	ALL SCNS	2.88	2.20	2.20	26.83	29.19	31.45	1093.9	0.000	0.68	0.68
813	ALL SCNS	2.93	2.39	2.40	27.23	29.70	31.80	1091.2	0.065	0.53	0.53
814	ALL SCNS	3.06	2.89	2.89	28.07	31.42	33.25	1092.8	0.039	0.17	0.17
815	ALL SCNS	3.14	3.08	3.07	28.61	28.64	30.70	-0.2	0.026	0.06	0.06
816	ALL SCNS	3.09	2.91	2.91	28.45	28.59	30.65	-0.2	0.043	0.18	0.18
817	ALL SCNS	2.94	2.40	2.41	28.82	29.00	31.10	-0.2	0.000	0.54	0.54
818	ALL SCNS	2.86	2.02	2.02	30.53	30.71	32.50	-0.2	0.078	0.84	0.84
819	ALL SCNS	2.89	1.94	1.94	35.23	34.49	35.86	-0.2	0.060	0.95	0.95
820	ALL SCNS	2.96	2.07	2.07	53.53	50.32	51.66	-0.2	0.000	0.89	0.89
821	ALL SCNS	2.95	2.28	2.29	62.34	60.13	61.96	-0.2	0.031	0.66	0.66
822	ALL SCNS	2.95	2.45	2.45	69.10	67.38	69.32	-0.2	0.026	0.50	0.51
823	ALL SCNS	3.02	2.81	2.81	74.31	73.21	74.81	-0.2	0.018	0.21	0.21
824	ALL SCNS	3.07	2.98	2.98	78.08	76.93	78.33	-0.2	0.012	0.09	0.09
825	ALL SCNS	3.18	3.18	3.18	82.27	82.12	81.95	-0.2	0.000	0.00	0.00
826	ALL SCNS	3.55	3.39	3.39	28.63	31.14	32.75	923.7	0.033	0.16	0.16
827	ALL SCNS	3.43	2.91	2.92	27.87	29.87	31.36	924.2	0.055	0.51	0.52
828	ALL SCNS	3.33	2.45	2.47	27.52	29.43	30.49	925.3	0.070	0.87	0.88
829	ALL SCNS	3.28	2.24	2.25	27.49	29.29	30.29	924.0	0.079	1.03	1.05
830	ALL SCNS	3.23	1.99	2.01	27.43	29.19	30.29	921.7	0.085	1.22	1.24
831	ALL SCNS	3.26	2.20	2.22	27.28	29.18	30.34	927.6	0.079	1.04	1.05
832	ALL SCNS	3.29	2.42	2.43	27.51	29.45	30.57	919.8	0.073	0.86	0.88
833	ALL SCNS	3.37	2.85	2.86	28.02	29.99	31.14	920.5	0.059	0.52	0.53
834	ALL SCNS	3.50	3.33	3.33	28.61	31.21	32.44	923.6	0.035	0.17	0.17
835	ALL SCNS	3.54	3.43	3.43	29.09	31.99	33.01	923.2	0.029	0.11	0.11
836	ALL SCNS	3.66	3.65	3.65	30.19	31.69	33.87	-0.2	0.000	0.01	0.01
837	ALL SCNS	3.64	3.54	3.54	29.93	29.81	31.32	-0.2	0.025	0.10	0.10
838	ALL SCNS	3.64	3.45	3.45	30.02	29.90	31.35	-0.2	0.034	0.19	0.19
839	ALL SCNS	3.56	3.08	3.08	29.38	29.43	30.80	-0.2	0.051	0.48	0.49
840	ALL SCNS	3.49	2.64	2.64	29.06	29.22	30.63	-0.2	0.066	0.84	0.85
841	ALL SCNS	3.44	2.39	2.40	28.97	29.19	30.49	-0.2	0.072	1.04	1.05
842	ALL SCNS	3.41	2.19	2.19	28.85	29.16	30.51	-0.2	0.076	1.21	1.22
843	ALL SCNS	3.42	2.38	2.39	29.22	29.45	30.76	-0.2	0.071	1.04	1.04
844	ALL SCNS	3.45	2.58	2.59	29.70	29.91	31.18	-0.2	0.064	0.86	0.87
845	ALL SCNS	3.52	2.99	2.99	31.08	31.12	32.34	-0.2	0.051	0.53	0.53
846	ALL SCNS	3.62	3.44	3.44	33.43	33.36	34.54	-0.2	0.029	0.18	0.18
847	ALL SCNS	3.67	3.54	3.54	37.17	36.99	38.20	-0.2	0.025	0.14	0.14
848	ALL SCNS	3.74	3.64	3.65	44.09	43.85	45.00	-0.2	0.016	0.09	0.09
849	ALL SCNS	3.80	3.79	3.80	49.84	53.04	55.38	-0.2	0.000	0.00	0.01
850	ALL SCNS	4.06	3.86	3.86	28.46	30.73	32.31	756.0	0.029	0.20	0.20
851	ALL SCNS	3.91	3.38	3.38	27.79	29.48	31.28	756.6	0.047	0.53	0.53
852	ALL SCNS	3.84	3.33	3.34	27.62	29.36	30.88	755.3	0.047	0.50	0.51
853	ALL SCNS	3.60	2.69	2.71	26.99	28.58	30.17	754.9	0.067	0.89	0.90
854	ALL SCNS	3.45	2.41	2.43	26.89	28.48	30.06	753.3	0.072	1.02	1.04
855	ALL SCNS	3.22	2.04	2.06	26.71	28.44	30.09	756.2	0.078	1.17	1.18
856	ALL SCNS	3.08	2.03	2.04	26.84	28.28	29.94	754.6	0.074	1.04	1.06
857	ALL SCNS	3.04	2.17	2.18	26.90	28.40	30.26	755.4	0.069	0.86	0.87
858	ALL SCNS	3.02	2.49	2.49	27.10	28.72	30.51	756.5	0.055	0.52	0.53

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 98.363 kPa

CONFIGURATION NO. 9 Single brush in position 1 with stubby rotor

FLUID: HYDROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (MPa)	AVG PRESS STATION 2 (MPa)	AVG PRESS STATION 5 (MPa)	AVG TEMP STATION 1 (K)	AVG TEMP STATION 2 (K)	AVG TEMP STATION 5 (K)	AVERAGE SHAFT SPEED (REV/S)	VENTURI 2 LEAKAGE RATE (Kg/S)	DELTA-P STA 1-5 (MPd)	DELTA-P STA 1-2 (MPd)
859	ALL SCNS	3.04	2.84	2.84	27.69	29.63	31.53	754.9	0.035	0.20	0.20
860	ALL SCNS	3.11	2.93	2.94	27.71	29.10	30.85	589.1	0.034	0.17	0.18
861	ALL SCNS	3.05	2.54	2.54	27.24	28.44	30.09	588.4	0.054	0.51	0.51
862	ALL SCNS	2.98	2.10	2.11	26.93	28.11	29.82	587.9	0.069	0.87	0.88
863	ALL SCNS	2.98	1.94	1.96	26.84	28.03	29.72	588.5	0.073	1.02	1.04
864	ALL SCNS	2.96	1.77	1.78	26.85	28.04	29.83	586.0	0.078	1.18	1.20
865	ALL SCNS	3.01	1.97	1.98	27.22	28.16	29.90	589.6	0.073	1.04	1.05
866	ALL SCNS	3.05	2.19	2.20	27.36	28.31	30.03	588.9	0.067	0.85	0.86
867	ALL SCNS	3.12	2.62	2.63	28.19	29.19	30.74	588.9	0.052	0.50	0.50
868	ALL SCNS	3.22	3.03	3.03	29.83	30.88	32.53	588.5	0.033	0.19	0.19
869	ALL SCNS	3.28	3.18	3.18	32.14	33.20	34.71	589.5	0.022	0.10	0.10
870	ALL SCNS	3.43	3.22	3.22	27.73	29.05	33.12	418.0	0.038	0.20	0.21
871	ALL SCNS	3.25	2.68	2.69	27.03	28.32	33.12	418.0	0.058	0.56	0.56
872	ALL SCNS	2.85	1.91	1.93	26.30	27.28	32.13	417.9	0.114	0.92	0.94
873	ALL SCNS	2.81	1.73	1.74	26.20	27.48	32.21	417.6	0.118	1.07	1.08
874	ALL SCNS	2.78	1.57	1.59	26.15	27.24	32.14	418.1	0.119	1.19	1.21
875	ALL SCNS	2.83	1.79	1.81	26.18	27.40	31.94	418.0	0.116	1.03	1.04
876	ALL SCNS	2.92	2.05	2.06	26.23	27.40	31.40	418.5	0.110	0.86	0.87
877	ALL SCNS	3.22	2.69	2.70	26.61	27.62	32.00	416.1	0.090	0.52	0.53
878	ALL SCNS	3.42	3.25	3.25	27.10	28.09	32.44	417.9	0.054	0.18	0.18
879	ALL SCNS	3.49	3.38	3.38	27.39	28.54	32.30	418.6	0.043	0.11	0.11
880	ALL SCNS	3.50	3.40	3.40	27.75	28.40	32.53	253.2	0.041	0.10	0.10
881	ALL SCNS	3.43	3.25	3.26	27.55	28.33	30.55	254.4	0.055	0.18	0.18
882	ALL SCNS	3.22	2.66	2.67	27.06	27.79	32.11	252.6	0.087	0.55	0.56
883	ALL SCNS	3.10	2.19	2.20	26.87	27.79	31.36	252.9	0.101	0.89	0.90
884	ALL SCNS	3.03	1.97	1.99	26.89	27.88	31.69	252.8	0.106	1.05	1.06
885	ALL SCNS	3.03	1.77	1.78	27.06	27.96	31.86	253.0	0.112	1.25	1.27
886	ALL SCNS	3.12	2.08	2.09	27.50	28.40	32.40	252.8	0.102	1.03	1.04
887	ALL SCNS	3.17	2.30	2.30	28.65	29.41	33.01	252.4	0.094	0.86	0.87
888	ALL SCNS	3.28	2.75	2.76	30.68	31.30	35.35	252.9	0.075	0.53	0.53
889	ALL SCNS	3.49	3.34	3.34	35.84	36.33	40.07	253.4	0.044	0.15	0.15
890	ALL SCNS	3.46	3.35	3.35	29.18	29.05	33.29	-0.2	0.015	0.11	0.11
891	ALL SCNS	3.51	3.35	3.35	28.84	28.78	32.30	-0.2	0.020	0.16	0.16
892	ALL SCNS	3.41	2.87	2.87	28.11	27.99	32.29	-0.2	0.033	0.54	0.54
893	ALL SCNS	3.30	2.42	2.42	27.38	27.62	31.70	-0.2	0.040	0.88	0.89
894	ALL SCNS	3.26	2.22	2.23	27.33	27.65	31.72	-0.2	0.041	1.03	1.04
895	ALL SCNS	3.22	1.99	1.99	27.15	27.63	31.37	-0.2	0.041	1.23	1.23
896	ALL SCNS	3.25	2.19	2.19	27.09	27.52	31.14	-0.2	0.043	1.06	1.06
897	ALL SCNS	3.29	2.40	2.41	27.22	27.46	31.65	-0.2	0.043	0.88	0.88
898	ALL SCNS	3.37	2.87	2.87	27.62	27.56	31.34	-0.2	0.040	0.50	0.50
899	ALL SCNS	3.48	3.31	3.31	28.20	27.96	32.44	-0.2	0.025	0.17	0.17
900	ALL SCNS	3.53	3.44	3.44	28.62	28.21	33.08	-0.2	0.018	0.09	0.09
901	ALL SCNS	3.63	3.62	3.62	30.39	39.97	47.13	-0.2	0.000	0.01	0.00

Appendix D

Data Tables—English Units

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.337 PSIA

CONFIGURATION NO. 2 Single brush in position 1

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)
125	ALL SCNS	786.90	782.69	151.55	164.67	-6.9	0.000	4.20
126	ALL SCNS	778.56	755.15	151.83	162.36	-7.5	0.158	23.41
127	ALL SCNS	769.67	720.76	150.52	159.79	-7.8	0.242	48.91
128	ALL SCNS	764.71	691.33	150.67	159.58	-8.4	0.297	73.39
129	ALL SCNS	757.92	660.04	150.18	159.11	-6.9	0.357	97.87
130	ALL SCNS	752.57	628.99	150.67	159.65	-6.3	0.398	123.57
131	ALL SCNS	748.25	599.91	150.66	159.74	-6.3	0.434	148.35
132	ALL SCNS	744.41	571.94	150.14	159.13	-6.3	0.458	172.47
133	ALL SCNS	747.22	598.80	151.09	159.74	-6.3	0.426	148.42
134	ALL SCNS	750.92	626.51	150.39	159.63	-6.6	0.387	124.42
135	ALL SCNS	755.90	656.57	150.22	158.73	-6.3	0.343	99.34
136	ALL SCNS	761.75	687.75	151.15	159.47	-6.6	0.293	74.00
137	ALL SCNS	767.69	718.93	150.67	159.13	-6.3	0.232	48.76
138	ALL SCNS	775.61	751.85	150.99	159.98	-6.3	0.146	23.76
139	ALL SCNS	785.78	782.01	151.22	161.81	-6.3	0.000	3.77
140	ALL SCNS	793.13	788.68	150.52	166.90	5143.1	0.000	4.46
141	ALL SCNS	789.65	766.15	150.80	162.75	5140.0	0.022	23.50
142	ALL SCNS	785.91	738.53	150.75	160.99	5138.4	0.070	47.38
143	ALL SCNS	784.77	737.48	150.95	160.59	5116.6	0.069	47.30
144	ALL SCNS	781.33	706.94	151.94	162.10	5153.1	0.124	74.39
145	ALL SCNS	777.43	677.58	151.20	161.29	5139.4	0.172	99.85
146	ALL SCNS	774.14	652.61	150.98	160.95	5102.8	0.202	121.53
147	ALL SCNS	770.74	617.66	150.70	160.29	5127.5	0.237	153.08
148	ALL SCNS	768.35	594.09	150.20	159.58	5096.9	0.258	174.27
149	ALL SCNS	769.17	616.27	150.51	159.79	5102.2	0.230	152.89
150	ALL SCNS	770.61	647.38	150.52	159.19	5090.9	0.227	123.23
151	ALL SCNS	774.16	701.05	149.89	158.66	5107.8	0.153	73.11
152	ALL SCNS	780.96	757.43	150.59	159.92	5115.6	0.023	23.53
153	ALL SCNS	783.32	757.30	151.10	161.93	-6.3	0.000	26.02
154	ALL SCNS	781.41	731.43	150.24	160.46	-6.3	0.057	49.98
155	ALL SCNS	778.47	704.77	150.33	159.81	-6.3	0.109	73.71
156	ALL SCNS	773.86	654.38	151.51	159.99	-6.3	0.170	119.48
157	ALL SCNS	770.67	622.50	151.08	159.82	-7.2	0.192	148.17
158	ALL SCNS	768.17	596.41	150.45	159.24	-6.6	0.226	171.76
159	ALL SCNS	768.80	619.34	150.86	159.35	-6.3	0.208	149.46
160	ALL SCNS	770.13	650.37	150.36	158.80	-7.2	0.165	119.76
161	ALL SCNS	773.83	702.16	151.43	160.12	-6.3	0.104	71.67
162	ALL SCNS	779.47	756.62	151.39	161.85	-6.6	0.000	22.85
163	ALL SCNS	785.88	787.09	151.58	177.07	-6.3	0.000	-1.21
164	ALL SCNS	781.54	755.55	151.68	169.41	15235.3	0.000	25.99
165	ALL SCNS	775.97	704.94	151.01	164.05	15227.2	0.110	71.04
166	ALL SCNS	769.09	648.61	151.21	162.33	15133.4	0.179	120.48
167	ALL SCNS	765.12	617.70	151.02	161.66	15087.8	0.225	147.42
168	ALL SCNS	761.69	588.10	150.78	161.10	15092.2	0.247	173.59
169	ALL SCNS	762.23	612.30	151.16	161.51	15121.3	0.226	149.92
170	ALL SCNS	763.14	638.70	152.04	162.83	15126.3	0.209	124.44
171	ALL SCNS	766.71	691.93	152.37	163.87	15032.2	0.138	74.78
172	ALL SCNS	772.59	747.28	153.53	168.91	15035.9	0.033	25.31
173	ALL SCNS	773.52	751.77	157.53	167.30	-6.3	0.019	21.75
174	ALL SCNS	768.00	692.09	159.36	167.53	-6.3	0.113	75.91
175	ALL SCNS	764.19	644.59	161.55	169.04	-6.3	0.161	119.60
176	ALL SCNS	761.60	615.62	164.03	171.11	-6.6	0.197	145.99
177	ALL SCNS	759.66	588.84	167.32	174.04	-6.3	0.190	170.82
178	ALL SCNS	760.12	611.18	170.70	177.17	-6.3	0.192	148.94

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.337 PSIA

CONFIGURATION NO. 2 Single brush in position 1

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)
179	ALL SCNS	761.07	637.57	174.71	180.70	-6.3	0.157	123.50
180	ALL SCNS	764.05	689.60	178.86	184.56	-6.6	0.106	74.46
181	ALL SCNS	769.07	743.70	184.04	189.79	-6.3	0.031	25.37
182	ALL SCNS	797.75	774.15	147.74	158.74	-8.1	0.072	23.60
183	ALL SCNS	799.11	748.98	148.32	158.51	-9.1	0.132	50.13
184	ALL SCNS	799.15	749.00	148.11	158.54	-7.5	0.132	50.15
185	ALL SCNS	798.99	724.88	148.29	158.78	-7.8	0.165	74.11
186	ALL SCNS	798.66	699.95	149.00	158.64	-8.4	0.200	98.70
187	ALL SCNS	796.41	672.71	149.55	159.12	-7.8	0.231	123.70
188	ALL SCNS	794.27	643.15	149.22	158.82	-8.8	0.261	151.11
189	ALL SCNS	792.72	619.88	149.05	158.56	-8.1	0.264	172.84
190	ALL SCNS	794.65	645.80	148.98	158.50	-7.5	0.247	148.84
191	ALL SCNS	797.43	674.78	149.31	158.51	-8.8	0.226	122.65
192	ALL SCNS	800.32	700.82	150.02	159.47	-7.8	0.201	99.50
193	ALL SCNS	803.28	728.44	150.02	159.64	-8.1	0.169	74.84
194	ALL SCNS	806.82	758.28	150.05	160.06	-8.8	0.130	48.53
195	ALL SCNS	811.61	785.98	149.92	160.43	-7.8	0.076	25.62
196	ALL SCNS	799.63	775.24	147.93	158.41	4891.9	0.097	24.38
197	ALL SCNS	799.06	724.04	148.03	157.98	4836.3	0.188	75.03
198	ALL SCNS	799.89	726.02	149.16	161.88	15045.6	0.181	73.87
199	ALL SCNS	800.16	775.76	148.90	163.82	14953.4	0.086	24.40
200	ALL SCNS	801.00	775.04	152.57	183.07	24310.3	0.082	25.97
201	ALL SCNS	800.74	725.37	152.01	175.89	25391.6	0.173	75.37
202	ALL SCNS	796.22	672.37	151.50	170.68	25172.2	0.245	123.86
203	ALL SCNS	793.01	644.56	151.28	169.25	25126.6	0.256	148.46
204	ALL SCNS	789.67	611.83	151.26	168.57	25087.8	0.284	177.83
205	ALL SCNS	790.43	638.51	151.64	169.55	25200.3	0.256	151.92
206	ALL SCNS	791.65	664.75	151.83	170.21	25220.3	0.269	126.90
207	ALL SCNS	796.93	725.53	152.54	173.36	25160.3	0.187	71.40
208	ALL SCNS	804.55	781.51	154.48	184.21	25052.2	0.085	23.04
209	ALL SCNS	803.26	777.81	150.25	161.50	-7.2	0.100	25.45
210	ALL SCNS	796.38	723.00	149.99	159.73	-9.4	0.194	73.38
211	ALL SCNS	790.99	668.96	150.07	160.52	-9.1	0.250	122.04
212	ALL SCNS	787.49	638.04	149.61	159.46	-9.4	0.253	149.44
213	ALL SCNS	785.34	615.88	149.76	159.69	-9.4	0.292	169.47
214	ALL SCNS	786.70	634.67	149.91	159.51	-9.7	0.254	152.03
215	ALL SCNS	788.82	666.00	150.13	159.56	-7.2	0.262	122.82
216	ALL SCNS	793.75	717.01	150.71	160.11	-6.6	0.190	76.74
217	ALL SCNS	801.77	776.84	151.11	161.31	-7.8	0.089	24.93
218	ALL SCNS	810.49	810.95	151.87	177.17	-7.2	0.000	-0.47
219	ALL SCNS	809.49	787.54	162.04	218.38	35478.8	0.082	21.95
220	ALL SCNS	796.61	722.01	160.20	197.11	35104.4	0.184	74.60
221	ALL SCNS	787.22	664.36	161.46	192.55	35273.8	0.237	122.86
222	ALL SCNS	781.00	631.97	163.52	191.88	35067.2	0.263	149.03
223	ALL SCNS	775.13	602.30	165.93	192.22	34936.3	0.291	172.82
224	ALL SCNS	773.71	624.35	169.83	196.34	35144.1	0.271	149.36
225	ALL SCNS	772.48	649.23	174.91	202.32	35010.3	0.244	123.25
226	ALL SCNS	773.48	698.81	182.23	213.82	35499.4	0.184	74.66
227	ALL SCNS	777.69	752.46	189.71	232.11	37670.6	0.097	25.23
228	ALL SCNS	770.65	746.19	196.28	203.50	-6.3	0.101	24.46
229	ALL SCNS	763.97	689.49	203.67	209.62	-6.3	0.194	74.49
230	ALL SCNS	758.87	634.22	211.69	216.55	-6.3	0.240	124.65
231	ALL SCNS	757.57	608.20	219.29	222.97	-6.6	0.248	149.37
232	ALL SCNS	756.40	582.91	225.61	227.75	-7.2	0.260	173.48
233	ALL SCNS	757.68	607.23	229.27	231.05	-7.2	0.238	150.46
234	ALL SCNS	758.86	635.62	232.95	234.97	-6.6	0.212	123.24
235	ALL SCNS	761.73	689.07	237.24	239.51	-7.2	0.158	72.66
236	ALL SCNS	766.26	742.81	240.67	243.77	-7.2	0.082	23.45
237	ALL SCNS	772.69	772.97	242.92	250.64	-7.2	0.000	-0.28

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.072 PSIA

CONFIGURATION NO. 3 2 Brushes far apart at stations 2 & 5

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 3 (PSIA)	AVG PRESS STATION 4 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 3 (R)	AVG TEMP STATION 4 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)
238	ALL SCNS	778.88	777.75	778.80	775.11	149.60	153.64	151.79	161.667	-9.1	0.00
239	ALL SCNS	778.98	768.74	769.79	755.49	149.64	151.36	150.40	156.999	-8.8	0.07
240	ALL SCNS	778.61	757.40	758.37	729.85	149.38	150.78	149.82	155.524	-8.8	0.12
241	ALL SCNS	778.40	747.65	748.59	705.56	149.30	150.66	149.87	155.549	-8.8	0.16
242	ALL SCNS	778.42	738.50	739.34	681.28	149.57	150.63	150.04	155.518	-9.1	0.19
243	ALL SCNS	778.24	729.06	729.91	655.07	149.30	150.45	149.89	155.395	-9.4	0.21
244	ALL SCNS	778.22	720.48	721.20	629.97	149.49	150.52	150.01	155.725	-9.4	0.23
245	ALL SCNS	779.54	713.79	714.62	605.20	149.29	150.36	149.85	155.653	-9.4	0.25
246	ALL SCNS	779.08	705.52	706.37	580.17	148.72	149.91	149.48	155.646	-9.4	0.27
247	ALL SCNS	778.14	705.79	706.40	555.28	148.94	150.01	149.62	155.785	-8.8	0.29
248	ALL SCNS	777.87	699.52	700.07	529.66	149.20	150.24	149.85	156.199	-9.4	0.30
249	ALL SCNS	778.28	708.09	708.73	557.67	148.92	150.10	149.63	155.636	-9.4	0.28
250	ALL SCNS	778.27	715.24	715.84	581.79	149.15	150.22	149.68	155.676	-9.4	0.26
251	ALL SCNS	778.58	723.54	724.21	608.44	148.94	150.01	149.48	155.381	-9.4	0.24
252	ALL SCNS	778.19	730.28	731.00	630.57	149.04	150.03	149.56	155.614	-9.4	0.22
253	ALL SCNS	778.53	738.79	739.61	657.45	149.13	150.20	149.67	155.799	-9.4	0.20
254	ALL SCNS	778.66	746.31	747.09	681.60	148.97	149.98	149.57	155.535	-9.4	0.17
255	ALL SCNS	778.93	754.47	755.31	708.11	149.05	150.15	149.61	155.723	-9.1	0.14
256	ALL SCNS	779.13	761.72	762.61	731.66	148.98	150.15	149.39	155.724	-8.1	0.10
257	ALL SCNS	779.18	770.61	771.67	756.81	149.03	150.39	149.75	156.338	-6.9	0.04
258	ALL SCNS	779.56	779.41	780.46	777.36	148.93	152.18	150.70	162.293	-6.6	0.00
259	ALL SCNS	779.47	780.83	781.75	780.38	149.16	169.18	175.82	180.379	-7.2	0.00
260	ALL SCNS	779.57			757.84	149.16	158.45	158.17	168.995	5103.8	0.01
261	ALL SCNS	779.22			704.89	149.12	151.97	151.75	158.778	5110.9	0.05
262	ALL SCNS	779.16			654.57	149.08	150.69	150.49	156.379	5085.3	0.11
263	ALL SCNS	778.76			606.02	149.24	150.48	150.20	155.810	5065.9	0.14
264	ALL SCNS	778.58			557.08	149.15	150.36	150.06	155.437	5057.8	0.17
265	ALL SCNS	778.59			532.18	149.43	150.62	150.30	155.477	5034.1	0.19
266	ALL SCNS	778.59			503.93	149.77	150.98	150.56	155.867	5008.4	0.20
267	ALL SCNS	778.58			483.78	149.87	150.96	150.82	155.726	4879.1	0.21
268	ALL SCNS	778.67			553.48	150.06	151.19	150.84	155.811	5009.4	0.18
269	ALL SCNS	778.81			605.61	150.03	150.95	150.71	155.581	4981.6	0.15
270	ALL SCNS	778.89			656.75	150.33	151.43	151.08	156.110	5045.6	0.12
271	ALL SCNS	779.19			707.43	150.16	151.33	151.06	156.477	5043.8	0.07
272	ALL SCNS	779.46			757.60	150.27	153.68	153.49	160.630	5055.0	0.02
273	ALL SCNS	779.58			780.97	151.56	190.90	191.22	183.279	5099.4	0.00
274	ALL SCNS	779.16	768.50	769.40	755.27	150.47	152.85	151.79	160.514	-6.3	0.02
275	ALL SCNS	778.96	745.12	745.91	704.72	150.26	151.63	150.94	157.130	-6.3	0.06
276	ALL SCNS	778.99	726.07	726.66	654.72	150.59	151.66	151.31	156.477	-6.3	0.11
277	ALL SCNS	778.55	709.59	709.99	605.41	150.62	151.71	151.39	156.383	-6.3	0.14
278	ALL SCNS	778.51	690.85	691.05	555.74	150.75	151.80	151.51	156.283	-6.3	0.17
279	ALL SCNS	778.10	672.37	672.62	502.50	150.90	151.90	151.73	156.695	-6.3	0.19
280	ALL SCNS	778.58	692.49	692.85	556.45	151.21	152.05	151.80	156.812	-6.9	0.17
281	ALL SCNS	778.64	712.18	712.64	607.93	151.45	152.22	152.22	156.888	-7.2	0.14
282	ALL SCNS	778.57	729.13	729.72	656.18	152.69	153.57	153.33	158.003	-7.5	0.11
283	ALL SCNS	778.86	748.77	749.46	709.69	154.29	155.24	154.89	159.591	-7.8	0.07
284	ALL SCNS	779.21	767.86	768.76	756.51	157.74	158.87	158.30	163.686	-7.8	0.02
285	ALL SCNS	779.44	780.82	781.79	780.45	160.70	169.43	172.61	179.177	-7.8	0.00
287	ALL SCNS	810.94			786.84	150.98	168.54	168.36	187.311	15231.9	0.04
288	ALL SCNS	811.21			740.00	150.98	157.36	157.18	169.639	14852.5	0.10
289	ALL SCNS	810.67			687.37	150.53	154.31	154.10	163.512	14809.4	0.11
290	ALL SCNS	810.90			637.24	150.72	153.91	153.77	161.595	15052.8	0.15
291	ALL SCNS	810.29			585.81	150.63	153.20	153.27	159.976	14987.2	0.19
292	ALL SCNS	809.25			533.41	150.75	153.32	153.04	159.620	14985.9	0.21

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.072 PSIA

CONFIGURATION NO. 3 2 Brushes far apart at stations 2 & 5

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 3 (PSIA)	AVG PRESS STATION 4 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 3 (R)	AVG TEMP STATION 4 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)
293	ALL SCNS	810.53			587.82	150.66	153.09	152.96	159.511	14940.9	0.19
294	ALL SCNS	810.60			636.78	150.58	152.98	152.86	159.869	14902.2	0.17
295	ALL SCNS	810.51			684.92	150.43	153.12	153.00	160.263	14900.6	0.14
296	ALL SCNS	810.49			736.60	150.52	153.93	153.87	162.880	14912.5	0.10
297	ALL SCNS	811.19			788.26	151.00	162.27	162.17	175.274	14692.5	0.05
298	ALL SCNS	811.26			812.15	152.66	211.42	211.97	210.284	14992.5	0.03
299	ALL SCNS	809.97	800.56	800.29	785.92	149.52	151.38	150.75	159.836	-8.1	0.05
300	ALL SCNS	810.03	780.47	780.15	735.79	149.39	150.51	150.20	157.208	-6.6	0.08
301	ALL SCNS	809.75	765.52	765.17	684.35	150.49	151.01	150.99	156.922	-6.3	0.11
302	ALL SCNS	809.88	754.74	753.89	633.85	151.07	151.15	151.17	156.773	-6.3	0.13
303	ALL SCNS	807.23	738.98	738.44	586.16	150.59	150.86	150.84	156.136	-6.3	0.15
304	ALL SCNS	804.00	720.05	719.62	519.40	150.17	150.61	150.27	155.563	-6.3	0.18
305	ALL SCNS	804.22	725.18	724.96	533.86	150.05	150.48	150.19	155.088	-7.8	0.17
306	ALL SCNS	805.31	740.78	740.29	585.96	150.52	150.82	150.67	155.331	-9.1	0.15
307	ALL SCNS	806.47	754.71	754.35	633.32	150.57	150.92	150.67	155.224	-9.4	0.13
308	ALL SCNS	807.63	767.84	767.41	683.15	150.64	150.94	150.92	155.113	-10.6	0.11
309	ALL SCNS	812.30	785.12	784.79	738.75	150.79	151.25	150.86	155.745	-11.6	0.08
310	ALL SCNS	822.54	812.68	812.38	798.96	151.50	152.60	151.84	157.748	-12.2	0.05
311	ALL SCNS	810.16	810.44	810.09	808.47	150.01	156.35	155.74	171.512	-12.2	0.03
312	ALL SCNS	813.89			789.84	155.57	186.12	185.85	215.997	25079.1	0.05
313	ALL SCNS	812.71			741.06	155.12	170.80	170.54	193.788	24801.3	0.08
314	ALL SCNS	812.34			686.57	154.47	165.82	165.56	183.849	24804.1	0.11
315	ALL SCNS	812.21			641.67	154.67	164.40	164.49	180.252	24940.9	0.12
316	ALL SCNS	809.55			538.64	154.46	163.20	163.28	177.470	25062.5	0.15
317	ALL SCNS	806.96			559.86	154.66	162.22	162.26	174.651	24923.4	0.17
318	ALL SCNS	807.11			585.28	155.29	163.07	163.14	175.793	24946.3	0.16
319	ALL SCNS	808.13			636.11	155.37	163.99	163.96	177.840	24988.1	0.14
320	ALL SCNS	809.28			685.60	155.59	165.17	165.17	180.391	24999.7	0.12
321	ALL SCNS	812.37			737.86	156.33	168.51	168.52	187.763	25022.8	0.09
322	ALL SCNS	816.14			793.78	157.33	183.42	183.10	210.697	24760.6	0.05
323	ALL SCNS	820.38			822.53	165.10	262.36	263.42	260.580	25210.9	0.02
324	ALL SCNS	809.90	799.85	799.66	784.33	150.49	152.69	151.90	160.267	-9.4	0.05
325	ALL SCNS	810.41	781.15	780.98	735.53	150.53	151.75	151.50	158.509	-7.8	0.09
326	ALL SCNS	809.90	766.06	765.84	682.76	150.65	151.51	151.34	157.202	-6.6	0.11
327	ALL SCNS	809.82	757.89	757.56	639.31	150.61	151.26	151.18	156.121	-6.6	0.12
328	ALL SCNS	809.81	744.32	743.86	583.81	151.32	151.46	151.59	156.330	-6.3	0.15
329	ALL SCNS	808.85	738.65	738.21	559.81	151.51	151.67	151.79	156.360	-6.3	0.16
330	ALL SCNS	809.61	746.72	746.41	587.34	151.88	152.05	152.06	156.774	-6.3	0.15
331	ALL SCNS	810.33	758.61	758.12	634.40	150.66	151.05	150.99	154.034	-6.3	0.13
332	ALL SCNS	810.35	772.64	772.34	687.58	150.32	150.93	150.69	153.936	-6.3	0.11
333	ALL SCNS	810.11	783.56	783.45	736.74	150.55	151.38	151.12	155.029	-6.3	0.10
334	ALL SCNS	810.47	800.14	800.15	785.78	150.74	152.18	151.50	157.064	-6.3	0.07
335	ALL SCNS	810.38	810.97	810.98	809.35	150.53	156.95	156.60	169.844	-6.3	0.05
336	ALL SCNS	815.05			793.32	164.22	210.47	210.37	239.897	35305.6	0.05
337	ALL SCNS	813.84			741.83	162.75	187.99	187.85	220.183	35074.4	0.09
338	ALL SCNS	811.02			687.85	161.68	180.97	181.22	209.380	35224.1	0.12
339	ALL SCNS	807.78			639.22	161.45	178.99	179.25	203.431	35513.4	0.15
340	ALL SCNS	805.06			584.68	160.67	176.59	176.74	198.231	35351.6	0.17
341	ALL SCNS	802.81			555.42	160.21	175.31	175.48	195.696	35333.4	0.18
342	ALL SCNS	801.71			578.30	160.87	176.53	176.70	197.593	35532.8	0.17
343	ALL SCNS	802.13			632.77	161.60	179.00	179.22	202.217	35649.4	0.15
344	ALL SCNS	801.96			680.10	162.12	181.42	181.78	207.369	35570.9	0.13
345	ALL SCNS	802.34			731.61	162.73	184.15	184.21	213.431	35545.6	0.11
346	ALL SCNS	806.05			782.36	165.76	207.19	207.08	237.246	36245.6	0.05
347	ALL SCNS	805.42			781.29	165.10	205.00	204.88	236.799	35423.8	0.05
348	ALL SCNS	807.72			809.24	175.92	346.25	347.91	343.354	34837.5	0.01
349	ALL SCNS	800.54	790.69	790.53	777.17	152.76	156.00	154.57	167.568	-6.3	0.04
350	ALL SCNS	797.14	768.02	767.92	720.89	152.43	153.47	152.76	160.292	-6.3	0.08
351	ALL SCNS	794.69	758.22	758.01	670.11	152.11	152.73	152.17	157.521	-6.6	0.11
352	ALL SCNS	792.22	745.24	744.95	617.66	151.78	152.33	151.63	156.283	-6.3	0.13
353	ALL SCNS	788.84	733.97	733.55	563.60	151.80	152.08	151.72	155.798	-6.3	0.14
354	ALL SCNS	786.20	728.44	728.01	536.71	152.45	152.76	152.35	155.989	-6.3	0.15
355	ALL SCNS	785.03	731.39	731.00	562.12	153.18	153.39	152.86	156.721	-6.3	0.15
356	ALL SCNS	783.93	736.96	736.72	610.30	154.17	154.21	153.92	157.508	-6.3	0.13
357	ALL SCNS	782.41	744.85	744.47	658.90	156.74	156.86	156.57	160.145	-6.3	0.11
358	ALL SCNS	782.73	756.40	756.10	710.39	159.01	159.04	158.86	162.353	-6.3	0.10
359	ALL SCNS	783.60	773.36	773.21	758.72	162.08	162.33	161.97	166.449	-6.3	0.07
360	ALL SCNS	785.18	785.68	785.55	784.70	166.27	169.73	170.45	183.139	-6.3	0.05

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.401 PSIA

CONFIGURATION NO. 4 2 Brushes tightly packed .. positions 3 & 4

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 2 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 2 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)	DELTA-P STA 1-2 (PSID)
362	ALL SCNS	810.21	810.49	786.44	150.99	152.31	165.98	-6.3	0.127	23.77	-0.28
363	ALL SCNS	805.32	805.57	754.26	150.58	151.82	164.97	-6.3	0.196	51.06	-0.25
364	ALL SCNS	801.92	802.22	727.27	150.32	151.42	164.15	-6.3	0.236	74.65	-0.31
365	ALL SCNS	798.92	799.33	697.56	150.02	151.16	163.81	-6.3	0.274	101.37	-0.40
366	ALL SCNS	795.43	795.84	670.17	149.88	151.11	163.45	-6.3	0.311	125.25	-0.41
367	ALL SCNS	791.92	792.33	642.73	149.68	150.78	163.33	-6.3	0.345	149.18	-0.41
368	ALL SCNS	788.67	789.12	611.90	149.49	150.38	163.21	-6.3	0.369	176.77	-0.44
369	ALL SCNS	786.91	787.32	589.58	149.30	150.43	163.41	-6.3	0.379	197.33	-0.41
370	ALL SCNS	784.78	785.24	558.93	149.42	150.55	163.52	-6.3	0.392	225.85	-0.46
371	ALL SCNS	778.81	779.36	530.53	149.22	150.19	163.17	-6.3	0.395	248.28	-0.55
372	ALL SCNS	780.86	781.41	560.93	149.33	150.40	163.11	-6.3	0.384	219.93	-0.55
373	ALL SCNS	782.59	782.99	582.41	149.48	150.36	163.09	-6.3	0.369	200.18	-0.40
374	ALL SCNS	784.77	785.35	609.55	149.44	150.29	163.13	-6.3	0.346	175.23	-0.57
375	ALL SCNS	787.68	788.16	640.40	149.45	150.74	163.30	-6.3	0.327	147.27	-0.49
376	ALL SCNS	790.54	791.06	666.61	149.38	150.59	163.13	-6.3	0.298	123.93	-0.52
377	ALL SCNS	793.96	794.55	695.05	149.70	150.90	163.50	-6.3	0.265	98.91	-0.59
378	ALL SCNS	798.71	799.38	727.19	149.73	150.66	163.67	-6.3	0.221	71.52	-0.67
379	ALL SCNS	804.17	804.81	756.67	150.04	150.99	164.42	-6.3	0.166	47.51	-0.64
380	ALL SCNS	809.43	810.01	786.26	150.10	151.25	165.14	-6.3	0.109	23.17	-0.58
381	ALL SCNS	817.90	818.41	818.29	150.48	152.55	175.58	-6.3	0.005	-0.40	-0.51
382	ALL SCNS	808.02	807.86	785.06	149.80	151.23	171.34	5043.1	0.054	22.96	0.16
383	ALL SCNS	803.20	802.33	730.43	149.49	150.59	166.93	5034.1	0.110	72.77	0.86
384	ALL SCNS	797.81	797.27	669.24	149.32	150.43	165.60	5155.0	0.179	128.56	0.54
385	ALL SCNS	794.00	793.51	616.22	149.04	150.33	164.94	5115.9	0.213	177.78	0.49
386	ALL SCNS	791.43	790.98	566.37	149.13	150.19	164.91	5032.2	0.238	225.06	0.45
387	ALL SCNS	790.29	789.87	541.60	148.94	150.19	164.70	4916.3	0.252	248.69	0.42
388	ALL SCNS	791.21	790.82	568.86	149.15	150.26	164.58	5031.9	0.233	222.35	0.39
389	ALL SCNS	793.08	792.68	618.07	149.45	150.57	164.48	5011.6	0.208	175.01	0.40
390	ALL SCNS	796.10	795.69	674.00	149.67	150.74	164.75	5009.4	0.174	122.09	0.41
391	ALL SCNS	799.59	799.07	726.06	149.88	150.81	165.29	4948.8	0.132	73.53	0.53
392	ALL SCNS	805.97	805.76	783.83	150.29	151.47	169.08	5027.2	0.058	22.14	0.21
393	ALL SCNS	806.98	807.83	783.06	150.70	151.92	166.33	-12.5	0.061	23.92	-0.85
394	ALL SCNS	802.87	803.61	727.04	150.45	151.49	165.49	-12.5	0.132	75.83	-0.74
395	ALL SCNS	797.60	798.41	673.58	150.37	151.52	164.43	-12.5	0.167	124.02	-0.81
396	ALL SCNS	793.51	794.39	618.47	150.19	151.14	164.42	-12.5	0.217	175.04	-0.88
397	ALL SCNS	790.00	790.82	566.50	149.97	151.02	164.34	-12.5	0.240	223.50	-0.81
398	ALL SCNS	788.56	789.44	540.09	149.72	150.69	164.23	-12.5	0.254	248.47	-0.88
399	ALL SCNS	789.80	790.60	567.07	149.78	150.74	164.29	-12.5	0.238	222.73	-0.80
400	ALL SCNS	792.09	793.01	620.05	149.76	150.79	164.02	-12.2	0.209	172.04	-0.92
401	ALL SCNS	795.04	795.94	671.63	149.93	150.69	164.18	-11.3	0.175	123.41	-0.89
402	ALL SCNS	798.94	799.67	725.58	150.16	151.05	164.34	-10.6	0.130	73.37	-0.72
403	ALL SCNS	805.98	806.88	785.36	150.49	151.47	166.86	-9.7	0.053	20.62	-0.90
404	ALL SCNS	810.44	811.30	810.99	150.54	152.72	178.04	-9.4	0.006	-0.54	-0.86
405	ALL SCNS	807.77	800.67	783.68	151.68	153.26	185.61	15267.2	0.058	24.09	7.10
406	ALL SCNS	803.53	796.90	730.72	150.95	152.28	174.90	14938.8	0.104	72.80	6.63
407	ALL SCNS	797.89	791.05	672.25	150.64	151.76	171.03	14941.6	0.157	125.64	6.84
408	ALL SCNS	792.41	785.24	618.85	150.37	151.74	168.77	15003.8	0.212	173.56	7.17
409	ALL SCNS	789.40	782.20	565.21	150.21	151.43	167.93	14852.5	0.240	224.20	7.20
410	ALL SCNS	787.70	780.50	537.91	150.05	151.36	167.66	14927.8	0.250	249.79	7.20
411	ALL SCNS	788.45	781.43	568.07	150.14	151.45	167.82	14962.5	0.232	220.38	7.02
412	ALL SCNS	790.19	783.17	617.72	150.23	151.48	168.22	14916.6	0.205	172.47	7.02
413	ALL SCNS	792.96	786.03	672.13	150.78	151.92	169.26	14964.7	0.171	120.83	6.93
414	ALL SCNS	796.07	789.30	723.46	150.92	152.04	170.76	14877.5	0.127	72.61	6.77
415	ALL SCNS	803.05	796.48	780.98	151.80	152.98	182.04	14879.7	0.052	22.07	6.57

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.401 PSIA

CONFIGURATION NO. 4 2 Brushes tightly packed .. positions 3 & 4

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 2 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 2 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)	DELTA-P STA 1-2 (PSID)
416	ALL SCNS	803.35	804.28	780.33	150.47	150.96	167.56	-6.3	0.054	23.02	-0.93
417	ALL SCNS	799.62	800.46	726.22	150.04	150.77	166.15	-6.3	0.109	73.40	-0.84
418	ALL SCNS	795.22	796.18	672.42	149.99	150.51	165.54	-6.3	0.162	122.80	-0.96
419	ALL SCNS	791.28	792.22	616.80	150.17	150.86	165.16	-6.3	0.199	174.48	-0.94
420	ALL SCNS	788.03	788.94	563.61	149.98	150.65	164.90	-6.3	0.226	224.41	-0.91
421	ALL SCNS	786.20	787.10	538.56	150.07	150.70	165.11	-6.3	0.236	247.64	-0.91
422	ALL SCNS	786.53	787.51	562.86	150.31	150.89	165.14	-6.3	0.223	223.67	-0.98
423	ALL SCNS	788.26	789.23	617.12	150.30	150.86	165.32	-6.3	0.193	171.14	-0.97
424	ALL SCNS	790.55	791.49	668.82	150.51	151.24	165.55	-6.3	0.162	121.74	-0.93
425	ALL SCNS	793.74	794.66	721.46	150.66	151.17	165.86	-6.3	0.119	72.29	-0.91
426	ALL SCNS	799.33	800.24	777.42	150.86	151.38	168.62	-7.2	0.056	21.91	-0.91
427	ALL SCNS	803.27	804.21	803.97	150.85	153.07	179.51	-6.6	0.005	-0.70	-0.94
428	ALL SCNS	803.18	785.52	779.92	158.87	160.95	199.71	25181.9	0.056	23.26	17.66
429	ALL SCNS	792.30	774.66	720.25	157.79	159.63	179.52	25145.6	0.114	72.05	17.64
430	ALL SCNS	786.88	768.83	664.54	156.26	158.14	171.65	25240.9	0.171	122.33	18.05
431	ALL SCNS	779.85	761.74	608.37	155.43	157.31	167.87	25175.9	0.211	171.48	18.12
432	ALL SCNS	775.36	757.15	552.70	154.54	156.49	165.32	25136.9	0.241	222.66	18.21
433	ALL SCNS	773.16	754.81	523.53	154.28	156.25	164.19	25076.6	0.256	249.63	18.35
434	ALL SCNS	773.87	755.60	552.66	154.88	156.74	165.42	25126.3	0.238	221.22	18.27
435	ALL SCNS	775.81	757.60	606.10	154.76	156.58	166.61	25161.6	0.207	169.71	18.21
436	ALL SCNS	778.28	760.49	655.25	155.55	157.47	168.88	25125.3	0.176	123.04	17.80
437	ALL SCNS	783.47	765.82	711.68	157.64	159.37	177.08	25055.9	0.117	71.79	17.65
438	ALL SCNS	788.80	771.29	766.16	159.02	160.74	196.13	25040.9	0.057	22.64	17.50
439	ALL SCNS	794.21	795.32	795.24	154.15	170.91	200.93	-7.2	0.005	-1.03	-1.11
440	ALL SCNS	788.59	789.83	762.17	151.70	152.09	156.48	-6.3	0.064	26.42	-1.24
441	ALL SCNS	783.54	784.60	709.05	152.11	152.20	153.88	-6.3	0.120	74.49	-1.06
442	ALL SCNS	778.21	779.31	652.55	151.22	151.43	152.06	-6.3	0.179	125.66	-1.10
443	ALL SCNS	774.46	775.74	599.41	151.04	151.21	151.12	-6.3	0.213	175.05	-1.28
444	ALL SCNS	772.01	773.13	547.58	151.85	152.01	151.85	-6.3	0.240	224.43	-1.12
445	ALL SCNS	770.53	771.62	520.41	151.45	151.52	151.70	-6.3	0.251	250.12	-1.09
446	ALL SCNS	771.47	772.58	549.29	152.37	152.22	152.06	-6.6	0.234	222.18	-1.11
447	ALL SCNS	773.40	774.46	599.19	152.07	152.15	152.06	-6.3	0.207	174.21	-1.07
448	ALL SCNS	776.02	777.21	650.86	151.82	151.89	152.18	-6.3	0.174	125.16	-1.19
449	ALL SCNS	781.20	782.33	706.68	152.81	152.67	153.52	-6.3	0.117	74.53	-1.13
450	ALL SCNS	786.99	788.09	762.59	153.14	153.09	156.54	-6.3	0.058	24.40	-1.10
451	ALL SCNS	792.88	761.96	770.24	168.00	170.70	231.09	35490.3	0.054	22.64	30.92
452	ALL SCNS	787.11	756.15	715.46	164.21	166.97	208.23	35003.8	0.113	71.65	30.96
453	ALL SCNS	781.33	750.31	658.01	161.79	164.48	193.32	34743.8	0.174	123.32	31.02
454	ALL SCNS	777.44	745.74	608.15	161.74	164.48	189.42	35175.0	0.205	169.29	31.70
455	ALL SCNS	772.56	740.55	552.05	160.13	162.86	184.62	35030.3	0.241	220.51	32.01
456	ALL SCNS	769.77	737.41	523.47	159.74	162.40	182.61	35052.8	0.256	246.31	32.37
457	ALL SCNS	769.87	736.86	548.78	160.60	163.25	184.82	35407.8	0.241	221.09	33.01
458	ALL SCNS	771.01	738.30	602.85	161.39	163.95	188.35	35538.8	0.208	168.16	32.70
459	ALL SCNS	772.93	740.75	650.68	161.95	164.45	192.60	35407.8	0.173	122.24	32.17
460	ALL SCNS	776.31	744.74	706.03	164.36	166.94	204.30	35382.2	0.124	70.28	31.57
461	ALL SCNS	781.11	750.02	757.46	167.83	170.42	228.78	35389.4	0.058	23.65	31.09
462	ALL SCNS	776.38	777.49	752.49	152.77	152.97	158.16	-6.3	0.066	23.88	-1.11
463	ALL SCNS	772.02	773.13	696.71	151.91	151.91	154.28	-6.3	0.129	75.31	-1.11
464	ALL SCNS	766.20	767.21	641.62	151.41	151.72	152.14	-6.3	0.187	124.58	-1.00
465	ALL SCNS	762.35	763.41	586.03	150.84	151.25	151.26	-6.6	0.222	176.32	-1.06
466	ALL SCNS	759.21	760.33	531.98	150.53	150.85	150.85	-6.6	0.250	227.23	-1.12
467	ALL SCNS	757.49	758.59	508.98	150.46	150.76	150.63	-7.2	0.259	248.52	-1.10
468	ALL SCNS	757.47	758.84	533.74	150.90	151.04	150.94	-6.6	0.244	223.73	-1.36
469	ALL SCNS	759.41	760.48	585.94	150.95	151.16	151.24	-6.9	0.213	173.47	-1.08
470	ALL SCNS	761.93	762.97	640.93	151.18	151.39	151.39	-6.6	0.178	121.01	-1.04
471	ALL SCNS	765.63	766.70	692.61	151.25	151.21	151.73	-6.9	0.130	73.02	-1.07
472	ALL SCNS	770.91	771.96	746.75	151.15	151.28	153.29	-6.9	0.063	24.15	-1.05
473	ALL SCNS	776.04	777.10	776.50	152.27	155.99	167.53	-7.8	0.000	-0.46	-1.06

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.366 PSIA

CONFIGURATION NO. 5 3 Brushes equally space: pos 1,3,5

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 2 (PSIA)	AVG PRESS STATION 4 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 2 (R)	AVG TEMP STATION 4 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)
475	ALL SCNS	797.62	797.71	797.54	796.60	153.22	160.82	166.23	175.839	-6.3	0.01
476	ALL SCNS	778.76	776.70	775.04	771.03	149.75	151.37	155.23	167.559	-6.3	0.02
477	ALL SCNS	778.69	771.70	766.07	753.42	149.64	150.46	152.18	158.363	-6.3	0.04
478	ALL SCNS	778.71	756.70	738.36	701.30	149.49	150.39	150.88	155.211	-6.3	0.08
479	ALL SCNS	778.53	744.87	713.35	650.46	149.23	150.22	150.51	154.151	-6.3	0.11
480	ALL SCNS	778.44	742.98	705.62	627.83	149.54	150.48	150.58	153.793	-6.3	0.13
481	ALL SCNS	778.24	738.31	694.93	604.43	149.54	150.40	150.50	153.722	-6.3	0.14
482	ALL SCNS	778.30	732.92	682.90	577.72	149.58	150.33	150.52	153.589	-6.3	0.15
483	ALL SCNS	778.32	727.66	672.57	552.92	149.26	150.16	150.20	153.425	-6.6	0.16
484	ALL SCNS	778.36	719.93	677.12	526.43	149.31	150.11	150.15	153.316	-6.3	0.18
485	ALL SCNS	778.27	714.87	671.51	502.93	149.24	150.14	150.11	153.285	-6.3	0.18
486	ALL SCNS	778.19	721.08	682.32	529.34	149.25	150.17	150.16	153.277	-6.6	0.17
487	ALL SCNS	778.18	727.35	692.36	556.69	149.32	150.17	150.06	153.199	-6.3	0.16
488	ALL SCNS	778.27	733.64	701.74	582.73	149.38	150.26	150.31	153.308	-6.3	0.15
489	ALL SCNS	778.43	739.37	709.46	604.21	149.44	150.20	150.26	153.449	-6.3	0.14
490	ALL SCNS	778.31	746.97	712.61	628.17	149.19	150.07	150.15	153.269	-6.3	0.12
491	ALL SCNS	778.60	753.70	722.56	654.77	149.20	150.11	150.29	153.589	-6.3	0.11
492	ALL SCNS	778.58	764.20	745.13	704.89	149.09	150.07	150.17	153.791	-6.3	0.08
493	ALL SCNS	778.80	774.54	768.45	754.37	149.09	150.23	150.77	155.280	-6.3	0.04
494	ALL SCNS	778.92	776.68	773.74	766.86	149.15	150.52	151.70	157.339	-6.3	0.02
495	ALL SCNS	779.00	779.80	780.01	780.09	149.15	158.65	169.53	173.389	-6.3	0.00
496	ALL SCNS	778.98			752.20	149.04	153.52	156.47	163.131	4990.6	0.04
497	ALL SCNS	778.65			702.00	149.04	151.72	152.62	157.071	4915.3	0.08
498	ALL SCNS	778.39			651.45	149.13	151.02	151.78	155.433	4971.3	0.11
499	ALL SCNS	778.28			602.78	149.28	151.10	151.59	154.653	4928.4	0.14
500	ALL SCNS	778.41			553.97	149.24	151.01	151.37	154.497	4990.3	0.16
501	ALL SCNS	778.25			505.40	149.34	151.12	151.23	154.396	5046.3	0.19
502	ALL SCNS	778.20			553.86	149.50	151.02	151.25	154.325	5040.3	0.17
503	ALL SCNS	778.21			607.02	149.25	150.85	151.12	154.294	5072.5	0.14
504	ALL SCNS	778.30			653.29	149.11	150.74	151.10	154.419	4985.3	0.11
505	ALL SCNS	778.41			705.85	149.85	151.43	152.12	155.697	4974.4	0.08
506	ALL SCNS	778.53			755.11	149.31	153.75	156.38	161.638	4938.4	0.04
507	ALL SCNS	778.65	779.55	779.67	779.76	149.11	162.06	176.69	176.308	-8.4	0.00
508	ALL SCNS	778.33	773.09	766.69	751.62	149.41	150.93	152.60	161.892	-8.1	0.03
509	ALL SCNS	778.60	773.86	768.30	754.22	149.22	150.15	150.93	156.839	-7.5	0.04
510	ALL SCNS	778.48	761.89	744.79	703.30	149.05	149.80	150.15	154.286	-6.3	0.07
511	ALL SCNS	778.33	748.19	720.36	651.21	149.10	149.76	150.02	153.498	-6.6	0.10
512	ALL SCNS	778.21	744.01	710.20	628.33	149.34	150.09	150.27	153.381	-6.3	0.11
513	ALL SCNS	778.29	739.87	699.40	604.14	149.08	149.89	149.89	153.044	-6.3	0.12
514	ALL SCNS	778.30	729.90	682.86	551.61	149.28	149.92	150.09	153.178	-6.3	0.15
515	ALL SCNS	778.12	714.77	674.77	501.81	149.29	149.97	150.01	153.224	-6.3	0.17
516	ALL SCNS	778.17	727.39	694.58	554.66	149.31	150.01	150.03	153.240	-6.3	0.16
517	ALL SCNS	778.38	741.32	708.50	607.53	149.25	149.94	150.03	153.122	-6.3	0.13
518	ALL SCNS	778.62	754.67	724.72	658.16	149.03	149.88	149.86	153.153	-8.1	0.10
519	ALL SCNS	778.44	764.91	746.96	708.49	149.18	149.94	150.23	153.419	-6.6	0.07
520	ALL SCNS	778.68	774.61	768.58	754.60	149.22	150.22	150.72	154.972	-6.9	0.04
521	ALL SCNS	779.02	779.91	780.21	779.92	149.12	154.83	163.14	169.446	-6.3	0.00
522	ALL SCNS	779.37			753.82	150.75	165.23	173.63	185.170	15144.4	0.03
523	ALL SCNS	779.14			701.57	150.38	157.72	162.04	170.621	15115.3	0.07
524	ALL SCNS	778.91			655.43	150.26	155.55	158.51	165.458	15207.5	0.10
525	ALL SCNS	778.82			601.30	150.50	154.37	156.39	162.232	15032.5	0.13
526	ALL SCNS	778.56			551.30	150.64	153.98	155.08	160.357	15090.6	0.16
527	ALL SCNS	778.70			507.72	150.99	153.82	154.51	159.413	15057.8	0.19
528	ALL SCNS	778.78			559.33	150.71	153.63	154.38	159.375	15071.3	0.17

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.366 PSIA

CONFIGURATION NO. 5 3 Brushes equally space: pos 1,3,5

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 2 (PSIA)	AVG PRESS STATION 4 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 2 (R)	AVG TEMP STATION 4 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)
529	ALL SCNS	778.58			603.47	150.84	153.49	154.68	159.955	14989.7	0.14
530	ALL SCNS	778.69			657.34	150.78	153.91	155.27	161.353	14987.2	0.11
531	ALL SCNS	778.99			705.50	150.99	155.42	158.08	164.935	14918.4	0.08
532	ALL SCNS	779.10			758.71	151.34	165.24	173.56	182.816	14937.2	0.04
533	ALL SCNS	778.91	779.87	780.29	780.31	150.15	159.81	173.59	174.607	-6.3	0.00
534	ALL SCNS	778.73	773.26	766.91	752.55	149.93	150.93	152.01	157.879	-6.3	0.03
535	ALL SCNS	778.28	759.50	741.04	702.69	150.14	150.69	151.17	155.127	-6.3	0.07
536	ALL SCNS	778.39	746.14	715.79	650.17	150.54	150.99	151.21	154.746	-6.3	0.10
537	ALL SCNS	778.35	738.00	694.12	602.64	151.30	151.40	151.58	154.731	-6.3	0.12
538	ALL SCNS	776.25	727.00	691.15	553.80	152.92	152.66	153.20	156.094	-6.3	0.14
539	ALL SCNS	772.94	710.69	674.54	501.97	155.40	154.96	155.50	158.415	-6.3	0.17
540	ALL SCNS	773.14	722.21	691.91	550.83	157.14	156.66	157.32	159.901	-6.6	0.15
541	ALL SCNS	773.65	733.11	703.29	599.09	158.81	158.33	159.22	161.461	-6.9	0.13
542	ALL SCNS	775.45	749.42	716.82	651.64	162.18	161.64	162.37	164.520	-6.9	0.10
543	ALL SCNS	776.91	761.46	741.73	704.05	166.00	165.25	166.08	168.278	-6.9	0.08
544	ALL SCNS	779.30	774.61	768.16	754.60	169.84	169.20	170.30	173.264	-6.6	0.04
545	ALL SCNS	782.39	783.32	783.67	783.49	173.42	175.42	185.02	185.775	-8.1	0.00
546	ALL SCNS	784.65			757.91	153.41	181.93	197.44	229.431	25240.3	0.04
547	ALL SCNS	783.94			709.92	152.89	168.26	176.16	206.728	25015.3	0.07
548	ALL SCNS	783.82			659.57	152.54	163.30	169.26	195.048	24972.2	0.09
549	ALL SCNS	783.34			609.66	152.07	159.61	163.64	185.243	25138.8	0.13
550	ALL SCNS	783.44			558.76	151.83	158.76	162.20	182.051	25247.5	0.15
551	ALL SCNS	783.29			507.11	151.91	158.34	161.51	179.861	25152.5	0.17
552	ALL SCNS	783.48			557.20	152.09	159.02	162.59	181.486	25282.8	0.15
553	ALL SCNS	783.07			609.40	152.08	158.86	162.52	181.362	25174.1	0.16
554	ALL SCNS	783.38			658.56	152.36	159.93	164.34	185.399	25237.2	0.12
555	ALL SCNS	783.60			708.95	152.80	163.47	169.57	194.971	25386.6	0.08
556	ALL SCNS	783.92			758.70	153.45	179.61	193.15	223.262	24768.1	0.04
557	ALL SCNS	782.18	781.97	782.98	782.23	148.15	155.22	166.22	177.785	-6.3	0.00
558	ALL SCNS	781.69	775.39	768.58	754.17	148.06	148.98	150.09	163.045	-6.3	0.03
559	ALL SCNS	781.46	763.33	741.57	703.11	147.84	148.63	149.19	160.135	-6.3	0.07
560	ALL SCNS	781.35	751.36	714.98	654.51	147.81	148.56	148.73	159.627	-6.3	0.09
561	ALL SCNS	781.35	741.30	687.49	603.56	147.65	148.44	148.64	159.057	-6.3	0.11
562	ALL SCNS	781.26	735.84	663.61	554.08	147.90	148.53	148.83	159.321	-6.3	0.14
563	ALL SCNS	781.28	726.98	639.10	503.81	147.99	148.55	148.82	159.560	-6.3	0.15
564	ALL SCNS	781.43	737.55	665.67	555.13	147.93	148.53	148.78	158.996	-6.3	0.13
565	ALL SCNS	781.35	747.09	690.76	605.27	148.03	148.44	148.74	159.065	-6.3	0.11
566	ALL SCNS	781.41	756.78	716.28	655.88	148.11	148.70	148.75	159.298	-6.3	0.09
567	ALL SCNS	781.54	767.16	743.47	706.68	147.87	148.51	148.65	159.213	-6.3	0.07
568	ALL SCNS	781.68	776.11	768.85	756.03	148.02	149.02	149.26	160.827	-6.3	0.04
569	ALL SCNS	781.94	781.75	782.73	781.77	147.85	153.78	163.12	174.346	-6.3	0.00
570	ALL SCNS	785.88			760.49	160.26	212.16	228.99	255.007	35117.5	0.03
571	ALL SCNS	785.24			714.27	158.85	183.87	197.18	234.636	35155.3	0.08
572	ALL SCNS	779.88			636.56	157.48	167.26	174.15	203.608	35021.3	0.19
573	ALL SCNS	780.06			661.36	158.24	169.25	177.01	207.198	35545.3	0.17
574	ALL SCNS	775.34			601.64	157.53	166.64	173.00	200.169	35245.3	0.20
575	ALL SCNS	768.08			542.72	156.24	163.77	169.09	192.743	34111.3	0.24
576	ALL SCNS	764.09			490.32	155.02	161.52	165.90	187.047	32790.6	0.26
577	ALL SCNS	764.38			543.57	156.14	163.57	168.72	191.619	33600.0	0.24
578	ALL SCNS	765.05			593.85	156.96	165.30	171.34	196.647	34045.9	0.20
579	ALL SCNS	765.95			644.49	157.62	167.91	174.97	203.356	34393.4	0.17
580	ALL SCNS	765.68			695.38	158.31	169.35	178.98	209.176	34214.4	0.15
581	ALL SCNS	769.79			747.27	163.06	212.37	226.24	251.204	35270.0	0.03
582	ALL SCNS	763.21	756.66	749.40	737.07	151.10	151.38	153.13	168.861	-6.3	0.05
583	ALL SCNS	760.51	740.01	714.66	680.42	150.72	150.60	151.49	163.786	-6.3	0.09
584	ALL SCNS	757.81	726.49	683.11	628.73	150.10	150.14	150.78	161.930	-6.3	0.12
585	ALL SCNS	755.36	713.44	655.67	577.79	149.97	149.93	150.51	161.135	-6.3	0.14
586	ALL SCNS	752.15	700.00	628.15	527.58	149.88	149.89	150.31	160.733	-6.3	0.15
587	ALL SCNS	748.77	686.37	600.92	472.77	149.56	149.71	150.25	160.595	-6.3	0.16
588	ALL SCNS	746.77	695.85	625.65	522.72	149.83	149.73	150.18	160.115	-6.3	0.15
589	ALL SCNS	745.60	705.54	650.12	571.62	149.95	149.84	150.34	160.155	-6.3	0.13
590	ALL SCNS	744.51	714.93	674.02	618.69	150.07	149.93	150.39	160.301	-6.3	0.11
591	ALL SCNS	744.40	725.89	701.26	668.68	150.06	150.01	150.49	160.633	-6.3	0.08
592	ALL SCNS	745.55	739.96	732.73	717.99	150.84	150.70	151.51	162.284	-6.3	0.03
593	ALL SCNS	747.12	746.78	747.75	746.89	151.51	154.76	162.81	173.049	-6.3	0.00

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.170 PSIA

CONFIGURATION NO. 6 2 Brushes far apart - positions 2 & 5

FLUID: NITROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 3 (PSIA)	AVG PRESS STATION 4 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 3 (R)	AVG TEMP STATION 4 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)
594	ALL SCNS	781.39	775.73	774.87	757.50	150.16	153.92	152.76	161.368	-6.3	0.05
595	ALL SCNS	781.24	762.49	761.69	706.22	149.28	151.30	150.61	155.995	-6.6	0.11
596	ALL SCNS	781.28	774.37	773.77	756.10	148.23	151.62	150.72	159.367	-6.3	0.07
597	ALL SCNS	781.21	760.10	759.36	705.52	148.39	150.16	149.39	154.851	-6.3	0.09
598	ALL SCNS	781.05	753.27	752.57	654.34	148.12	149.31	148.92	153.329	-6.3	0.13
599	ALL SCNS	780.90	752.04	751.49	604.24	147.76	149.02	148.57	152.516	-6.3	0.15
600	ALL SCNS	780.79	747.88	747.31	555.99	147.63	148.64	148.44	151.968	-6.3	0.17
601	ALL SCNS	780.70	743.61	743.01	506.74	148.08	148.76	148.57	152.273	-6.3	0.18
602	ALL SCNS	780.70	749.01	748.29	555.24	147.91	148.87	148.54	151.889	-6.3	0.17
603	ALL SCNS	780.73	755.31	754.59	606.22	147.74	148.55	148.22	151.551	-6.3	0.14
604	ALL SCNS	780.85	760.62	759.86	656.86	148.17	149.06	148.87	151.960	-6.9	0.12
605	ALL SCNS	781.13	762.00	761.13	707.58	148.06	149.17	148.91	152.325	-6.3	0.09
606	ALL SCNS	781.26	773.57	772.69	756.59	147.97	149.62	149.11	153.678	-7.5	0.05
607	ALL SCNS	781.57	782.68	781.85	781.50	147.98	153.61	153.53	165.504	-7.2	0.00
608	ALL SCNS	786.46	774.44	769.68	763.07	159.91	195.63	196.69	228.587	35103.8	0.07
609	ALL SCNS	785.11	746.86	740.94	709.22	157.20	171.47	170.92	194.398	35088.4	0.18
610	ALL SCNS	784.80	728.64	722.33	658.50	156.50	168.32	167.80	187.555	35095.6	0.23
611	ALL SCNS	784.24	714.42	707.96	612.20	156.42	167.10	166.59	184.229	35036.3	0.26
612	ALL SCNS	783.97	704.76	698.37	558.92	156.03	166.04	165.46	181.816	34887.5	0.29
613	ALL SCNS	783.83	709.82	703.72	510.31	155.70	165.57	165.02	180.764	34747.2	0.30
614	ALL SCNS	784.15	718.45	712.24	559.33	156.42	167.14	166.60	183.227	35281.3	0.28
615	ALL SCNS	790.93	735.93	729.84	614.92	157.55	169.12	168.80	186.665	35528.8	0.25
616	ALL SCNS	791.23	745.69	740.01	666.15	157.93	170.16	169.68	189.807	35080.6	0.21
617	ALL SCNS	791.77	760.32	754.46	718.25	157.94	172.98	172.57	196.672	35085.6	0.16
618	ALL SCNS	792.50	780.00	774.49	767.92	159.89	189.24	188.94	222.907	35094.1	0.08
619	ALL SCNS	790.10	777.11	773.42	765.18	153.85	168.86	168.47	189.940	25041.3	0.07
620	ALL SCNS	789.38	753.30	749.48	713.79	152.86	161.93	161.51	176.250	25057.8	0.13
621	ALL SCNS	788.89	734.19	730.29	660.49	152.41	159.12	158.79	170.240	25048.8	0.19
622	ALL SCNS	788.88	714.82	710.79	612.68	152.56	158.10	157.82	167.960	25050.0	0.23
623	ALL SCNS	788.87	705.59	701.34	563.89	152.71	158.09	157.71	167.077	25052.8	0.25
624	ALL SCNS	789.04	718.56	714.73	514.97	153.13	158.71	158.09	167.492	25048.8	0.25
625	ALL SCNS	788.99	724.04	720.11	564.64	152.66	158.38	157.75	167.468	25051.3	0.23
626	ALL SCNS	789.08	732.65	728.73	614.60	152.53	158.47	158.06	168.190	25054.7	0.21
627	ALL SCNS	789.28	741.23	737.39	665.21	152.59	158.96	158.51	169.542	25065.6	0.19
628	ALL SCNS	789.42	755.88	751.85	714.62	153.08	161.00	160.53	173.697	25052.2	0.14
629	ALL SCNS	789.90	776.50	772.99	753.10	153.66	168.99	168.70	189.564	25032.5	0.07
630	ALL SCNS	788.17	776.61	774.61	763.13	149.51	155.11	154.69	164.279	14950.6	0.07
631	ALL SCNS	787.75	753.17	751.26	710.28	149.41	152.59	152.28	158.856	14945.0	0.12
632	ALL SCNS	787.53	739.52	737.49	662.21	149.64	152.66	152.32	157.849	14950.6	0.16
633	ALL SCNS	787.51	727.03	724.89	610.16	149.46	152.05	151.74	156.973	14960.0	0.18
634	ALL SCNS	787.39	726.17	723.95	561.18	149.51	151.72	151.52	156.437	14945.6	0.21
635	ALL SCNS	787.51	734.70	732.83	536.56	149.88	152.05	151.85	156.802	14960.9	0.21
636	ALL SCNS	787.50	737.00	735.11	563.00	149.99	152.01	151.77	156.911	14956.6	0.20
637	ALL SCNS	787.52	740.82	738.90	612.07	149.70	152.11	151.91	156.709	14934.1	0.19
638	ALL SCNS	787.77	746.89	744.86	664.03	149.93	152.49	152.33	157.531	14951.9	0.15
639	ALL SCNS	787.98	758.07	755.90	712.86	149.68	152.62	152.53	158.647	14940.0	0.12
640	ALL SCNS	788.40	778.48	776.51	765.24	149.71	158.96	158.68	167.845	14947.5	0.05
641	ALL SCNS	787.47	776.70	775.78	761.49	149.13	151.46	151.25	155.893	5039.4	0.06
642	ALL SCNS	787.17	756.81	755.73	711.65	148.91	150.45	150.32	153.976	5020.3	0.11
643	ALL SCNS	787.08	739.60	738.73	660.67	148.58	149.94	149.64	152.944	5018.4	0.14
644	ALL SCNS	786.86	726.65	725.54	609.72	148.66	149.70	149.56	152.851	5027.8	0.17
645	ALL SCNS	786.94	724.49	723.38	562.45	149.35	150.44	150.07	153.388	5034.1	0.19
646	ALL SCNS	787.04	735.16	734.17	537.96	149.22	150.06	149.85	153.169	5029.7	0.20
647	ALL SCNS	786.95	738.39	737.37	561.93	148.99	149.86	149.66	152.919	5040.3	0.19
648	ALL SCNS	787.15	745.70	744.63	612.52	148.68	149.62	149.41	152.668	5013.8	0.17
649	ALL SCNS	787.17	750.16	749.20	661.56	148.37	149.39	149.10	152.465	5014.4	0.14
650	ALL SCNS	787.20	759.01	757.85	712.45	148.49	149.77	149.44	152.966	5043.4	0.11
651	ALL SCNS	787.41	776.01	775.02	762.81	148.68	150.70	150.46	154.621	5019.4	0.06
652	ALL SCNS	787.42	776.59	775.72	759.00	148.81	150.17	149.68	153.442	-9.4	0.06
653	ALL SCNS	787.10	757.75	756.95	709.68	149.12	150.20	149.64	152.824	-9.4	0.10
654	ALL SCNS	787.03	748.29	747.34	660.87	149.10	150.06	149.51	152.621	-8.1	0.13
655	ALL SCNS	787.06	743.46	742.60	612.56	150.22	151.01	150.48	153.435	-7.5	0.14
656	ALL SCNS	787.03	748.80	748.01	560.49	150.92	151.45	150.94	154.043	-7.8	0.16
657	ALL SCNS	787.11	755.92	755.05	611.64	150.36	151.13	150.55	153.747	-6.3	0.14
658	ALL SCNS	787.10	761.80	761.05	661.68	149.52	150.51	149.98	153.247	-6.3	0.12
659	ALL SCNS	787.25	765.04	764.29	712.03	150.09	151.17	150.49	153.778	-6.3	0.09
660	ALL SCNS	787.49	778.07	777.38	763.97	150.60	152.14	151.39	155.423	-6.3	0.05
661	ALL SCNS	787.79	789.20	788.61	788.73	150.45	161.34	162.65	169.639	-6.3	0.00

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.303 PSIA

CONFIGURATION NO. 7 3 Brushes equally spaced - positions 1,3,5

FLUID: NITROGEN

RDG AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 2 (PSIA)	AVG PRESS STATION 4 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 2 (R)	AVG TEMP STATION 4 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)
662 ALL SCNS	780.44	775.49	771.03	763.41	149.59	149.99	151.82	158.111	-7.8	0.04
663 ALL SCNS	780.24	764.47	744.90	709.84	150.04	150.53	151.03	155.470	-8.1	0.07
664 ALL SCNS	779.97	757.32	724.25	663.94	149.92	150.32	150.85	154.380	-8.8	0.10
665 ALL SCNS	779.95	746.71	699.00	611.23	149.71	150.11	150.53	153.888	-9.1	0.12
666 ALL SCNS	779.60	738.12	692.79	561.01	149.43	149.92	150.32	153.521	-8.8	0.15
667 ALL SCNS	779.57	732.68	688.00	532.23	149.50	149.83	150.24	153.419	-7.5	0.15
668 ALL SCNS	779.58	737.88	697.63	559.77	149.44	150.13	150.36	153.356	-8.1	0.16
669 ALL SCNS	779.95	749.20	707.29	612.23	149.63	150.02	150.48	153.497	-7.5	0.13
670 ALL SCNS	779.86	759.18	723.72	660.97	149.48	149.85	150.35	153.497	-6.9	0.11
671 ALL SCNS	779.96	769.14	750.13	715.29	149.40	149.99	150.32	154.005	-7.2	0.07
672 ALL SCNS	780.07	776.60	772.22	763.69	149.83	150.42	151.35	156.621	-7.8	0.02
673 ALL SCNS	780.27	780.48	782.01	785.69	150.17	152.49	157.48	171.200	-9.1	0.00
674 ALL SCNS	784.76	775.56	768.19	766.77	160.31	204.18	230.75	246.369	35145.9	0.04
675 ALL SCNS	784.51	763.79	740.74	723.84	159.37	185.69	199.05	228.629	35136.9	0.09
676 ALL SCNS	783.84	750.14	706.94	666.19	158.82	176.66	189.24	213.549	35155.3	0.11
677 ALL SCNS	783.46	735.94	675.82	615.83	158.42	173.61	182.57	205.088	35181.3	0.15
678 ALL SCNS	783.03	719.04	643.04	563.16	158.13	170.96	177.94	197.532	35036.9	0.19
679 ALL SCNS	783.05	712.18	632.83	537.59	158.16	170.45	177.48	195.801	35070.0	0.20
680 ALL SCNS	782.92	705.99	625.64	512.88	158.01	169.92	176.24	194.420	35086.9	0.21
681 ALL SCNS	782.88	721.04	648.84	565.47	158.69	172.64	179.88	200.004	35810.0	0.18
682 ALL SCNS	783.10	733.81	674.22	615.84	158.46	172.62	180.51	201.994	35148.8	0.16
683 ALL SCNS	783.28	746.43	701.67	664.30	158.91	175.06	185.19	208.176	35129.1	0.14
684 ALL SCNS	783.65	757.38	731.78	713.48	159.28	180.06	193.25	219.452	35132.5	0.10
685 ALL SCNS	784.33	773.24	765.36	764.23	160.34	199.99	218.21	241.258	35132.2	0.05
686 ALL SCNS	781.78	772.57	764.12	760.67	154.58	174.21	184.77	211.820	25064.4	0.05
687 ALL SCNS	781.36	761.50	737.03	712.58	154.04	166.84	172.41	192.758	25072.2	0.08
688 ALL SCNS	781.14	748.91	707.29	660.66	153.76	164.12	168.27	184.825	25055.0	0.11
689 ALL SCNS	780.77	736.27	677.63	611.19	153.66	162.15	165.74	179.533	25061.3	0.13
690 ALL SCNS	781.21	723.83	650.88	560.67	153.09	160.60	163.72	175.394	25062.5	0.16
691 ALL SCNS	780.50	707.52	635.01	508.19	153.26	160.14	162.79	173.303	25075.6	0.19
692 ALL SCNS	780.67	723.13	652.51	561.11	153.41	160.95	163.99	175.102	25060.3	0.16
693 ALL SCNS	780.87	736.31	678.01	613.12	153.53	161.48	165.14	177.458	25070.0	0.14
694 ALL SCNS	780.85	746.98	703.66	660.05	153.81	162.52	166.57	180.638	25042.5	0.12
695 ALL SCNS	781.26	758.73	733.22	711.13	154.71	165.41	170.50	187.998	25076.6	0.09
696 ALL SCNS	781.54	772.76	764.27	760.75	155.39	176.47	186.76	211.216	25102.8	0.05
697 ALL SCNS	779.65	774.23	767.88	761.40	151.40	162.06	167.17	179.888	14928.1	0.03
698 ALL SCNS	779.37	763.72	742.34	710.04	150.91	157.24	159.69	169.371	14929.7	0.07
699 ALL SCNS	779.21	752.12	718.26	659.23	150.66	155.63	157.06	164.846	14923.4	0.11
700 ALL SCNS	779.01	740.88	684.58	607.36	150.66	154.06	155.55	161.651	14895.0	0.14
701 ALL SCNS	778.83	728.21	662.86	556.77	150.88	153.64	154.89	160.377	14909.7	0.15
702 ALL SCNS	778.69	710.24	639.40	506.54	150.55	153.43	154.36	159.411	14976.9	0.18
703 ALL SCNS	778.99	725.12	652.19	557.27	150.60	153.19	154.33	159.481	14927.8	0.17
704 ALL SCNS	778.74	737.57	676.79	605.63	150.66	153.31	154.75	160.099	14929.4	0.14
705 ALL SCNS	779.26	748.86	709.28	659.13	150.91	153.71	155.04	161.126	14948.4	0.12
706 ALL SCNS	779.14	760.40	737.79	709.15	150.87	154.27	156.21	163.261	14932.8	0.09
707 ALL SCNS	779.41	773.46	766.26	759.49	151.25	161.69	166.23	176.295	14947.8	0.04
708 ALL SCNS	778.88	774.22	767.82	759.11	150.00	152.61	154.03	159.148	5039.1	0.04
709 ALL SCNS	778.72	763.45	739.95	706.26	150.19	151.78	152.55	156.823	5061.3	0.08
710 ALL SCNS	778.68	753.19	714.82	657.49	149.90	151.27	151.94	155.688	5050.6	0.10
711 ALL SCNS	778.47	742.46	688.63	605.96	150.06	151.24	151.82	155.307	5043.4	0.12
712 ALL SCNS	777.88	728.76	664.39	558.17	150.91	151.83	152.30	155.672	5043.8	0.14
713 ALL SCNS	774.96	708.04	643.19	500.89	150.66	151.88	152.16	155.470	5054.1	0.16
714 ALL SCNS	773.61	720.36	661.81	553.98	151.07	152.14	152.44	156.232	5051.9	0.20
715 ALL SCNS	773.47	735.31	679.95	605.60	151.16	152.02	152.43	155.983	5036.9	0.15
716 ALL SCNS	773.59	744.88	703.49	648.54	151.27	151.95	152.58	156.364	5004.4	0.16
717 ALL SCNS	774.34	757.46	733.94	702.78	151.95	152.77	153.43	157.498	5040.3	0.09
718 ALL SCNS	776.43	771.74	765.14	757.74	152.48	155.00	156.30	160.910	5028.1	0.07
719 ALL SCNS	774.89	768.49	759.10	745.87	153.56	152.56	154.04	158.397	-7.2	0.08
720 ALL SCNS	772.03	756.03	732.20	696.38	153.32	152.47	153.74	156.962	-6.3	0.11
721 ALL SCNS	768.93	744.69	706.89	649.74	152.98	152.40	153.50	156.504	-6.3	0.12
722 ALL SCNS	749.14	714.11	660.36	574.71	150.39	150.65	151.21	154.465	-6.3	0.12
723 ALL SCNS	748.97	702.47	648.18	528.85	150.46	150.94	151.43	154.550	-6.3	0.15
724 ALL SCNS	748.88	694.82	646.90	501.04	150.79	151.22	151.50	154.917	-6.3	0.15
725 ALL SCNS	748.80	700.77	657.29	527.47	150.89	151.31	151.65	155.112	-6.3	0.14
726 ALL SCNS	748.86	714.43	664.52	579.79	151.12	151.67	151.88	155.166	-6.3	0.11
727 ALL SCNS	749.07	724.64	686.92	628.67	151.06	151.43	151.81	155.275	-6.3	0.10
728 ALL SCNS	749.07	733.70	711.24	677.50	150.92	151.57	151.77	155.314	-6.3	0.07
729 ALL SCNS	749.15	744.65	737.81	728.31	151.34	151.90	152.47	156.775	-6.3	0.04
730 ALL SCNS	749.32	749.62	751.28	754.93	152.17	154.67	160.81	173.869	-6.3	0.00

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.165 PSIA

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG	SCAN	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)
740	1	789.80	760.96	151.19	154.89	-9.4	0.098	28.84
740	2	786.13	742.23	150.83	154.74	-9.4	0.137	43.91
740	3	785.33	730.97	150.60	154.27	-9.4	0.163	54.36
740	4	785.40	725.21	150.83	154.19	-9.4	0.158	60.19
740	5	785.02	728.06	150.71	154.03	-9.4	0.154	56.96
740	6	785.48	733.40	150.83	154.03	-9.4	0.141	52.08
740	7	786.19	733.75	150.89	154.11	-9.4	0.155	52.44
740	8	783.17	713.27	150.65	154.35	-9.4	0.187	69.90
740	9	781.38	697.58	151.07	154.11	-9.4	0.215	83.80
740	10	780.79	687.30	150.89	153.80	-9.4	0.208	93.49
740	11	780.27	685.70	150.77	153.72	-9.4	0.208	94.56
740	12	781.18	684.79	150.95	153.96	-9.4	0.208	96.38
740	13	781.51	686.46	150.77	153.88	-6.3	0.206	95.05
740	14	781.00	688.55	150.66	153.56	-9.4	0.198	92.44
740	15	781.56	695.64	150.72	153.96	-6.3	0.193	85.92
740	16	781.59	693.35	150.77	153.57	-6.3	0.211	88.24
740	17	781.00	683.97	150.66	153.72	-6.3	0.214	97.03
740	18	780.40	677.86	150.54	153.80	-9.4	0.221	102.54
740	19	779.95	670.63	150.48	153.96	-9.4	0.224	109.32
740	20	779.11	668.83	150.71	153.41	-6.3	0.223	110.28
740	21	779.26	668.35	150.60	153.88	-6.3	0.223	110.90
740	22	778.86	660.37	150.24	154.11	-9.4	0.235	118.50
740	23	779.00	665.98	150.18	154.11	-6.3	0.222	113.02
740	24	777.79	656.55	150.60	153.72	-6.3	0.241	121.24
740	25	777.92	652.24	150.24	153.64	-6.3	0.245	125.68
740	26	775.75	632.80	150.54	153.88	-9.4	0.260	142.95
740	27	774.61	624.47	150.66	154.03	-6.3	0.278	150.14
740	28	774.57	625.93	150.71	153.57	-6.3	0.271	148.65
740	29	774.84	618.83	150.48	153.96	-6.3	0.290	156.01
740	30	774.18	620.02	150.36	153.95	-6.3	0.271	154.16
740	31	774.41	620.93	150.30	154.11	-9.4	0.281	153.47
740	32	774.22	623.57	150.72	153.80	-9.4	0.278	150.64
740	33	774.99	617.25	150.12	153.41	-6.3	0.276	157.74
740	34	773.38	606.21	150.30	153.49	-9.4	0.285	167.17
740	35	773.73	600.93	150.30	153.95	-6.3	0.293	172.80
740	36	772.13	590.25	150.18	153.33	-6.3	0.297	181.88
740	37	771.78	587.25	150.54	153.56	-9.4	0.301	184.53
740	38	772.71	591.01	150.13	153.96	-9.4	0.293	181.70
740	39	771.60	591.01	150.48	153.64	-9.4	0.298	180.59
740	40	773.22	592.25	150.30	153.57	-6.3	0.294	180.96
740	41	772.41	580.87	150.01	153.25	-6.3	0.313	191.54
740	42	770.20	571.14	150.13	153.72	-9.4	0.312	199.05
740	43	769.71	564.83	150.36	153.96	-6.3	0.319	204.88
740	44	769.12	550.59	150.30	153.49	-9.4	0.338	218.53
740	45	768.77	546.29	150.13	153.88	-6.3	0.331	222.48
740	46	768.07	545.04	150.24	153.88	-6.3	0.329	223.04
740	47	769.81	548.10	150.01	153.49	-6.3	0.339	221.72
740	48	768.71	551.51	150.24	153.64	-9.4	0.336	217.21
740	49	769.68	548.03	149.71	153.49	-9.4	0.352	221.65
740	50	768.49	534.97	150.01	153.49	-6.3	0.353	233.51
740	51	768.01	526.99	149.89	153.25	-6.3	0.341	241.02
740	52	766.19	508.03	150.18	153.56	-6.3	0.349	258.15
740	53	765.97	509.00	150.13	153.56	-6.3	0.359	256.97
740	54	766.12	511.58	149.89	153.17	-6.3	0.345	254.54

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.165 PSIA

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG	SCAN	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)
740	55	766.30	514.77	149.89	153.17	-9.4	0.345	251.53
740	56	767.49	520.68	149.89	153.41	-6.3	0.367	246.81
740	57	767.06	513.59	149.77	153.41	-6.3	0.372	253.47
740	58	765.51	500.82	149.95	153.33	-6.3	0.382	264.69
740	59	765.34	497.55	150.07	153.33	-6.3	0.372	267.80
740	60	765.09	487.48	149.95	153.57	-6.3	0.359	277.61
740	61	765.24	486.37	149.65	153.41	-6.3	0.366	278.87
740	62	765.20	487.34	150.01	153.72	-6.3	0.362	277.86
740	63	765.34	491.37	149.71	153.72	-6.3	0.357	273.98
740	64	765.27	495.11	149.89	153.33	-6.3	0.341	270.15
740	65	764.90	502.06	149.77	153.49	-6.3	0.341	262.83
740	66	764.55	494.15	149.77	153.80	-6.3	0.359	270.40
740	67	764.30	488.60	150.07	153.49	-6.3	0.373	275.70
740	68	765.31	488.46	149.65	153.56	-9.4	0.373	276.85
740	69	764.78	480.67	149.83	153.33	-6.3	0.366	284.11
740	70	763.99	475.05	150.01	153.18	-6.3	0.367	288.93
740	71	764.20	483.03	149.89	153.64	-6.3	0.364	281.17
740	72	764.05	480.67	150.13	153.41	-6.3	0.366	283.38
740	73	763.85	483.52	149.89	153.57	-6.3	0.362	280.33
740	74	764.22	480.40	149.42	153.56	-6.3	0.376	283.82
740	75	763.00	469.29	150.07	153.64	-6.3	0.374	293.71
740	76	762.00	457.97	149.89	153.49	-6.3	0.378	304.03
740	77	762.13	456.93	150.07	153.95	-6.3	0.378	305.20
740	78	762.02	455.75	150.18	153.80	-6.3	0.377	306.27
740	79	762.24	457.00	150.01	153.57	-6.3	0.375	305.24
740	80	762.62	459.65	149.65	153.49	-6.3	0.388	302.97
740	81	763.06	471.58	150.07	153.64	-6.3	0.377	291.49
740	82	763.91	476.93	150.24	153.80	-9.4	0.379	286.98
740	83	762.56	463.94	150.24	153.88	-9.4	0.368	298.61
740	84	761.65	452.69	150.01	153.72	-9.4	0.372	308.96
740	85	760.91	442.77	150.18	153.57	-6.3	0.390	318.14
740	86	760.67	434.50	150.13	153.65	-6.3	0.389	326.17
740	87	759.83	423.81	149.95	153.88	-6.3	0.392	336.03
740	88	760.53	425.13	149.95	153.88	-6.3	0.387	335.40
740	89	760.45	431.10	149.65	154.11	-9.4	0.381	329.35
740	90	760.71	439.51	149.83	153.64	-6.3	0.383	321.20
740	91	760.77	443.40	149.77	153.64	-6.3	0.386	317.38
740	92	759.48	419.16	149.89	153.72	-9.4	0.399	340.33
740	93	759.65	417.28	149.83	153.48	-6.3	0.397	342.37
740	94	759.12	410.13	150.01	153.72	-9.4	0.393	348.99
740	95	759.00	409.93	150.06	153.64	-6.3	0.397	349.07
740	96	759.40	408.82	149.83	153.56	-6.3	0.395	350.59
740	97	759.12	409.99	149.71	153.72	-6.3	0.395	349.13
740	98	759.33	410.89	149.71	153.64	-6.3	0.395	348.43
740	99	759.02	413.33	149.71	153.72	-6.3	0.391	345.69
740	100	758.99	415.07	149.71	153.64	-6.3	0.405	343.92
740	101	758.21	399.44	149.59	153.49	-6.3	0.402	358.77
740	102	757.30	385.63	149.95	153.80	-6.3	0.410	371.68
740	103	757.32	384.17	149.65	153.80	-6.3	0.416	373.15
740	104	757.07	381.53	149.83	153.80	-9.4	0.393	375.54
740	105	756.19	368.54	149.83	153.88	-9.4	0.389	387.65
740	106	756.47	374.38	149.71	153.57	-6.3	0.423	382.10
740	107	757.63	382.09	149.65	153.64	-9.4	0.410	375.54
740	108	757.25	379.99	149.71	153.80	-6.3	0.421	377.25
740	109	756.51	357.02	149.77	153.57	-9.4	0.435	399.49

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.165 PSIA

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG SCAN	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)
740 110	755.15	335.07	149.77	153.80	-6.3	0.407	420.08
740 111	755.15	337.30	149.77	153.64	-6.3	0.430	417.85
740 112	755.15	341.95	149.89	153.80	-9.4	0.418	413.20
740 113	754.90	334.80	149.77	153.80	-6.3	0.415	420.10
740 114	755.01	343.13	149.54	153.80	-9.4	0.416	411.89
740 115	755.07	342.85	149.53	153.80	-9.4	0.415	412.22
740 116	755.54	354.10	149.83	153.80	-6.3	0.424	401.44
740 117	754.03	315.70	149.42	153.80	-6.3	0.431	438.32
740 118	752.83	300.29	149.71	153.96	-6.3	0.438	452.55
740 119	752.60	297.71	149.65	153.95	-9.4	0.426	454.88
740 120	752.91	291.68	149.71	154.11	-6.3	0.428	461.23
740 121	752.50	295.43	149.59	153.80	-6.3	0.430	457.07
740 122	752.39	294.46	149.71	153.80	-9.4	0.431	457.92
740 123	753.22	300.15	149.71	153.96	-9.4	0.425	453.07
740 124	753.08	305.57	149.54	153.80	-9.4	0.427	447.52
740 125	752.83	306.67	149.89	153.72	-6.3	0.441	446.16
740 126	752.15	283.48	149.65	153.64	-9.4	0.432	468.67
740 127	752.25	280.15	149.65	154.27	-6.3	0.441	472.10
740 128	751.49	270.92	149.54	154.11	-6.3	0.431	480.57
740 129	751.34	272.65	149.65	153.10	-9.4	0.444	478.69
740 130	751.02	265.84	149.54	153.96	-6.3	0.433	485.18
740 131	750.67	263.43	149.77	153.49	-6.3	0.445	487.24
740 132	750.89	265.64	149.71	153.49	-6.3	0.429	485.26
740 133	751.27	273.21	149.54	153.88	-6.3	0.440	478.06
740 134	750.58	262.58	149.77	153.80	-9.4	0.456	487.99
740 135	749.56	248.70	149.65	153.65	-9.4	0.429	500.86
740 136	749.24	242.31	149.71	154.27	-9.4	0.448	506.93
740 137	749.14	241.55	149.83	154.03	-9.4	0.441	507.59
740 138	749.70	239.94	149.89	154.03	-6.3	0.444	509.76
740 139	749.32	240.85	149.65	154.27	-9.4	0.444	508.47
740 140	748.90	242.37	149.48	153.41	-6.3	0.440	506.53
740 141	750.18	250.02	149.65	153.80	-6.3	0.440	500.17
740 142	750.33	256.48	149.77	152.71	-6.3	0.440	493.85
740 143	749.52	253.00	149.95	153.33	-6.3	0.452	496.52
740 144	749.21	245.22	149.71	154.03	-6.3	0.441	503.98
740 145	749.52	242.37	149.65	153.65	-9.4	0.447	507.15
740 146	749.17	238.42	149.83	153.41	-9.4	0.445	510.76
740 147	748.65	237.03	149.71	153.88	-9.4	0.442	511.62
740 148	749.11	237.73	149.59	153.80	-6.3	0.443	511.38
740 149	749.21	241.33	149.65	153.10	-6.3	0.440	507.88
740 150	748.72	247.25	149.89	153.33	-9.4	0.436	501.48
740 151	750.39	255.36	149.54	153.72	-6.3	0.439	495.02
740 152	750.05	254.11	149.65	153.57	-6.3	0.447	495.94
740 153	748.93	243.77	149.65	153.18	-6.3	0.441	505.15
740 154	748.96	242.65	149.48	153.64	-9.4	0.442	506.31
740 155	749.21	239.32	149.65	154.11	-6.3	0.444	509.89
740 156	748.76	236.12	149.60	153.57	-6.3	0.442	512.63
740 157	748.65	237.30	149.71	153.80	-6.3	0.441	511.34
740 158	748.58	238.35	149.59	153.57	-9.4	0.442	510.23
740 159	748.41	245.85	149.71	153.65	-9.4	0.437	502.56
740 160	748.84	251.40	149.77	153.80	-9.4	0.439	497.44
740 161	749.21	255.02	149.83	153.65	-9.4	0.446	494.18
740 162	748.89	247.94	149.83	153.88	-6.3	0.442	500.95
740 163	749.17	243.77	149.95	153.96	-6.3	0.443	505.41
740 164	748.37	239.61	149.83	152.87	-9.4	0.442	508.76

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.165 PSIA

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG	SCAN	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)
740	165	748.75	236.69	149.95	153.96	-6.3	0.442	512.06
740	166	748.02	236.55	149.71	153.88	-6.3	0.440	511.47
740	167	747.70	238.01	149.89	154.11	-9.4	0.442	509.69
740	168	749.43	239.94	149.83	154.35	-6.3	0.437	509.49
740	169	749.21	250.02	149.89	154.27	-6.3	0.436	499.19
740	170	748.55	254.67	150.01	154.11	-6.3	0.439	493.87
740	171	748.51	247.45	149.71	154.27	-9.4	0.444	501.06
740	172	748.85	242.10	149.65	154.11	-9.4	0.440	506.75
740	173	748.58	240.50	149.83	153.88	-6.3	0.442	508.08
740	174	748.40	237.03	149.77	153.96	-6.3	0.442	511.37
740	175	748.20	235.71	149.65	154.03	-9.4	0.439	512.49
740	176	747.97	236.76	149.95	154.50	-6.3	0.440	511.22
740	177	748.66	241.89	149.71	153.88	-6.3	0.436	506.76
740	178	748.86	248.42	149.77	154.42	-9.4	0.434	500.44
740	179	748.76	255.50	149.77	154.43	-6.3	0.437	493.26
740	180	748.15	245.85	149.71	154.19	-6.3	0.443	502.30
740	181	748.43	243.49	149.89	154.35	-6.3	0.438	504.94
740	182	748.30	237.66	149.83	154.74	-6.3	0.441	510.64
740	183	748.06	236.20	149.89	154.43	-6.3	0.439	511.86
740	184	747.88	235.99	149.95	154.50	-9.4	0.441	511.89
740	185	747.52	227.66	149.89	154.50	-6.3	0.443	519.86
740	186	747.52	228.84	149.89	154.11	-9.4	0.440	518.68
740	187	747.89	233.70	149.59	154.11	-6.3	0.435	514.19
740	188	748.37	241.90	150.07	154.35	-9.4	0.439	506.47
740	189	747.77	233.97	150.19	154.66	-6.3	0.446	513.80
740	190	746.94	219.89	150.01	154.58	-6.3	0.447	527.05
740	191	746.67	216.96	150.36	154.97	-9.4	0.441	529.71
740	192	746.56	215.64	149.95	154.50	-6.3	0.444	530.91
740	193	746.55	211.96	150.07	154.27	-6.3	0.441	534.59
740	194	746.14	211.82	150.24	154.58	-9.4	0.445	534.32
740	195	746.56	211.06	150.07	154.66	-9.4	0.442	535.49
740	196	746.86	218.92	150.07	154.35	-6.3	0.440	527.95
740	197	746.48	225.44	150.30	154.19	-9.4	0.441	521.04
740	198	746.97	223.98	150.18	154.66	-9.4	0.451	523.00
740	199	746.28	208.29	150.30	154.66	-9.4	0.446	537.99
740	200	745.82	204.54	150.60	154.89	-9.4	0.444	541.28
740	201	745.61	197.25	150.13	154.27	-9.4	0.448	548.37
740	202	745.78	194.82	150.13	154.50	-9.4	0.444	550.96
740	203	745.43	190.16	150.07	154.74	-9.4	0.453	555.27
740	204	744.95	187.67	149.89	154.66	-9.4	0.444	557.29
740	205	745.02	194.82	150.24	154.35	-6.3	0.445	550.20
740	206	745.37	194.82	150.30	154.66	-6.3	0.447	550.55
740	207	744.97	184.68	150.42	155.05	-9.4	0.455	560.29
740	208	744.70	177.88	150.19	154.74	-9.4	0.448	566.82
740	209	744.57	175.72	150.01	154.58	-9.4	0.454	568.85
740	210	744.31	169.47	150.42	154.74	-9.4	0.455	574.84
740	211	743.68	159.54	150.36	154.50	-6.3	0.453	584.14
740	212	743.63	157.80	150.42	154.82	-9.4	0.453	585.83
740	213	743.65	156.07	150.54	154.97	-6.3	0.455	587.58
740	214	743.53	159.61	150.30	154.74	-9.4	0.446	583.91
740	215	744.00	166.98	150.07	154.89	-6.3	0.451	577.02
740	216	743.76	160.73	150.18	154.74	-9.4	0.455	583.04
740	217	742.99	151.29	150.24	154.74	-9.4	0.453	591.70
740	218	742.96	150.24	150.30	154.97	-6.3	0.455	592.72
740	219	742.71	139.55	150.13	154.50	-9.4	0.454	603.16

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.165 PSIA

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG SCAN	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)
740 220	742.64	138.23	150.36	155.36	-6.3	0.454	604.41
740 221	742.71	139.89	150.19	154.81	-9.4	0.455	602.81
740 222	742.56	138.86	150.48	154.89	-9.4	0.455	603.70
740 223	742.53	143.78	150.24	154.82	-9.4	0.448	598.75
740 224	742.71	150.59	150.42	154.50	-9.4	0.454	592.12
740 225	742.78	150.86	150.42	154.81	-6.3	0.455	591.92
740 226	742.95	143.86	150.13	154.50	-9.4	0.455	599.09
740 227	742.82	140.80	150.42	154.97	-6.3	0.455	602.02
740 228	742.26	137.33	150.13	154.50	-6.3	0.455	604.93
740 229	741.83	126.08	150.18	154.81	-6.3	0.454	615.75
740 230	741.35	119.21	150.30	154.97	-6.3	0.455	622.14
740 231	741.58	120.04	150.36	154.58	-6.3	0.453	621.55
740 232	741.52	124.77	150.30	154.11	-6.3	0.452	616.75
740 233	742.16	126.43	150.07	153.10	-6.3	0.455	615.73
740 234	741.59	118.03	150.36	154.51	-6.3	0.454	623.57
740 235	741.03	113.79	150.30	154.43	-6.3	0.454	627.25
740 236	740.89	107.69	150.24	154.35	-9.4	0.454	633.20
740 237	740.79	100.59	150.24	154.66	-6.3	0.454	640.19
740 238	740.29	99.13	150.19	154.35	-6.3	0.455	641.16
740 239	740.73	98.93	150.18	154.19	-6.3	0.455	641.80
740 240	740.36	98.03	150.18	154.42	-6.3	0.454	642.33
740 241	740.22	101.01	150.13	154.74	-6.3	0.455	639.22
740 242	740.30	105.32	150.18	154.43	-9.4	0.455	634.98
740 243	740.06	100.87	150.19	154.27	-6.3	0.455	639.18
740 244	740.26	94.90	149.95	154.19	-6.3	0.455	645.36
740 245	740.29	87.89	150.01	154.82	-9.4	0.454	652.40
740 246	739.99	85.04	150.30	154.43	-9.4	0.455	654.95
740 247	739.25	84.21	150.19	154.42	-6.3	0.454	655.03
740 248	739.88	83.31	150.30	154.43	-9.4	0.455	656.57
740 249	739.56	83.72	150.30	154.27	-9.4	0.455	655.84
740 250	739.25	82.69	150.07	154.43	-6.3	0.455	656.56
740 251	739.67	83.03	150.30	154.27	-9.4	0.455	656.64
740 252	739.21	80.25	150.01	154.51	-9.4	0.455	658.96
740 253	739.11	74.49	150.07	154.35	-9.4	0.454	664.62
740 254	738.78	71.65	150.30	154.43	-9.4	0.454	667.13
740 255	738.76	69.84	150.19	154.19	-9.4	0.454	668.92
740 256	738.73	69.01	150.18	154.58	-9.4	0.454	669.73
740 257	739.04	69.43	150.01	154.42	-9.4	0.455	669.62
740 258	738.96	70.05	149.95	154.43	-6.3	0.455	668.90
740 259	738.48	70.19	149.83	153.88	-6.3		668.30
740 260	738.69	69.22	150.24	154.43	-6.3		669.47
740 261	738.58	68.94	150.07	154.58	-9.4		669.65
740 262	738.63	69.14	149.83	154.12	-6.3		669.49
740 263	739.00	69.01	150.07	154.43	-9.4		669.99
740 264	738.30	69.70	150.42	154.50	-6.3		668.60
740 265	738.45	69.49	150.24	154.58	-9.4		668.96
740 266	738.87	69.63	149.83	154.50	-6.3		669.24
740 267	739.08	69.08	149.95	154.58	-9.4		670.00
740 268	738.53	68.52	149.77	154.27	-6.3		670.01
740 269	738.38	69.35	150.07	154.11	-9.4		669.03
740 270	738.14	68.80	150.13	154.11	-9.4		669.33
740 271	738.80	68.94	150.13	154.43	-9.4		669.86
740 272	738.45	69.01	150.18	154.66	-9.4		669.44
740 273	738.25	68.86	150.19	154.35	-6.3		669.39
740 274	738.37	68.52	150.07	154.50	-9.4		669.85

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.165 PSIA

CONFIGURATION NO. 8 Single Brush - position 1

FLUID: NITROGEN

RDG	SCAN	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	AVERAGE LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)
740	275	737.92	69.01	149.95	154.27	-6.3		668.92
740	276	738.48	68.94	149.89	154.50	-9.4		669.55
740	277	738.55	68.94	150.01	154.50	-9.4		669.61
740	278	738.76	68.80	149.77	154.58	-9.4		669.96
740	279	738.24	68.94	150.07	154.58	-9.4		669.30
740	280	738.10	68.23	150.01	154.27	-6.3		669.87
740	281	738.00	68.73	149.83	155.05	-6.3		669.27
740	282	737.81	69.16	150.48	154.27	-9.4	0.455	668.65
740	283	738.38	68.80	149.95	154.50	-9.4	0.455	669.58
740	284	737.96	68.66	150.19	154.89	-9.4	0.455	669.30
740	285	738.02	68.94	150.30	154.74	-9.4	0.455	669.09
740	286	737.82	68.86	150.30	154.51	-6.3	0.455	668.96
740	287	737.92	76.58	150.24	154.43	-9.4	0.425	661.34
740	288	739.43	111.23	150.24	154.35	-6.3	0.449	628.20
740	289	739.88	121.71	150.01	154.27	-6.3	0.444	618.17
740	290	741.17	158.45	150.18	154.97	-9.4	0.443	582.72
740	291	742.64	185.03	150.01	154.74	-9.4	0.411	557.61
740	292	743.65	230.79	150.13	154.58	-9.4	0.427	512.86
740	293	744.81	250.44	150.19	154.27	-9.4	0.426	494.37
740	294	746.76	292.17	150.36	154.42	-6.3	0.426	454.59
740	295	748.44	329.32	150.42	154.27	-6.3	0.393	419.12
740	296	748.16	331.40	150.30	154.58	-9.4	0.405	416.76
740	297	749.21	353.41	150.42	154.42	-9.4	0.390	395.80
740	298	749.83	364.93	150.36	154.50	-6.3	0.395	384.90
740	299	750.54	384.03	150.36	154.50	-9.4	0.382	366.52
740	300	751.37	384.65	150.13	154.27	-9.4	0.386	366.72
740	301	751.21	392.36	150.66	154.42	-6.3	0.378	358.85
740	302	752.98	422.29	150.54	154.58	-6.3	0.322	330.69
740	303	753.61	449.23	150.24	154.42	-6.3	0.355	304.38
740	304	753.54	446.94	150.42	154.27	-9.4	0.356	306.60
740	305	754.41	459.72	150.60	154.11	-6.3	0.352	294.69
740	306	754.52	456.58	150.48	153.95	-6.3	0.355	297.94
740	307	753.22	468.10	151.01	154.50	-9.4	0.328	285.11
740	308	754.69	474.78	150.89	154.50	-6.3	0.347	279.91
740	309	755.63	493.87	150.77	154.35	-6.3	0.318	261.76
740	310	756.75	508.45	150.83	154.19	-9.4	0.324	248.31
740	311	758.57	555.94	150.89	154.11	-6.3	0.304	202.63
740	312	760.00	584.91	150.83	153.95	-9.4	0.274	175.09
740	313	761.58	607.88	150.77	154.42	-9.4	0.219	153.71
740	314	761.85	608.51	150.89	154.35	-6.3	0.263	153.34
740	315	763.01	637.95	151.19	154.19	-9.4	0.235	125.06
740	316	764.23	656.21	150.89	154.27	-9.4	0.213	108.03
740	317	764.40	660.79	151.13	154.03	-6.3	0.213	103.61
740	318	766.85	682.24	151.13	154.03	-6.3	0.192	84.60
740	319	766.95	681.54	151.13	153.64	-9.4	0.191	85.41
740	320	773.38	743.35	150.89	154.97	-9.4	0.121	30.04
740	321	773.31	746.05	151.42	154.27	-9.4	0.095	27.25
740	322	775.05	754.23	151.48	154.42	-6.3	0.068	20.82
740	323	774.99	758.88	151.65	154.43	-6.3	0.044	16.11
740	324	776.60	763.95	151.60	154.97	-6.3	0.033	12.64
740	325	776.38	765.07	152.07	154.97	-9.4	0.032	11.31
740	326	777.08	766.53	152.01	154.89	-9.4	0.030	10.55
740	327	776.60	766.52	151.77	155.44	-9.4	0.029	10.08
740	328	776.78	767.29	152.19	155.20	-9.4	0.028	9.49
740	329	777.09	768.19	152.01	155.05	-9.4	0.027	8.90
740	330	777.36	768.53	152.19	155.75	-9.4	0.026	8.83
740	331	777.34	768.68	152.48	155.60	-6.3	0.026	8.66
740	332	777.16	769.44	152.36	155.75	-6.3	0.025	7.71
740	333	777.71	769.78	152.19	155.67	-9.4	0.025	7.93

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.268 PSIA

CONFIGURATION NO. 9 Single brush in position 1 with stubby rotor

FLUID: HYDROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 2 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 2 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	VENTURI 2 LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)	DELTA-P STA 1-2 (PSID)
805	ALL SCNS	440.66	362.78	363.51	48.54	53.41	57.44	65691.3	0.131	77.15	77.88
806	ALL SCNS	431.66	330.39	331.55	47.96	52.51	56.68	65526.3	0.150	100.11	101.27
807	ALL SCNS	423.80	299.72	301.37	47.71	52.23	56.31	65650.6	0.163	122.42	124.08
808	ALL SCNS	413.00	255.82	257.78	47.34	51.54	55.72	65663.8	0.169	155.22	157.18
809	ALL SCNS	406.95	231.88	234.05	47.26	51.54	55.61	65858.1		172.90	175.07
810	ALL SCNS	409.50	253.31	255.22	47.42	51.62	55.52	65885.6		154.28	156.19
811	ALL SCNS	411.44	285.16	286.79	47.69	51.85	55.90	65269.4		124.65	126.28
812	ALL SCNS	417.70	318.39	319.55	48.29	52.54	56.61	65631.9		98.15	99.31
813	ALL SCNS	424.41	347.26	347.96	49.02	53.46	57.25	65470.0	0.143	76.45	77.15
814	ALL SCNS	444.39	419.50	419.23	50.52	56.56	59.85	65565.6	0.086	25.16	24.88
815	ALL SCNS	455.07	446.01	445.93	51.50	51.54	55.27	-12.5	0.057	9.13	9.06
816	ALL SCNS	448.33	422.39	422.51	51.21	51.47	55.17	-12.5	0.095	25.82	25.94
817	ALL SCNS	426.96	348.72	349.13	51.87	52.21	55.99	-12.5		77.83	78.24
818	ALL SCNS	415.16	292.86	293.68	54.95	55.28	58.50	-12.5	0.172	121.48	122.30
819	ALL SCNS	418.92	280.87	281.83	63.41	62.08	64.56	-12.5	0.133	137.08	138.04
820	ALL SCNS	429.65	299.99	300.70	96.36	90.58	92.99	-12.5		128.95	129.66
821	ALL SCNS	427.73	331.40	331.95	112.22	108.24	111.53	-12.5	0.068	95.77	96.33
822	ALL SCNS	428.38	354.77	355.19	124.39	121.28	124.78	-12.5	0.058	73.19	73.61
823	ALL SCNS	438.00	407.18	407.27	133.75	131.78	134.65	-12.5	0.039	30.73	30.82
824	ALL SCNS	445.67	432.09	432.01	140.54	138.48	141.00	-12.5	0.026	13.65	13.58
825	ALL SCNS	460.75	460.66	460.56	148.09	147.82	147.50	-12.5	0.000	0.19	0.09
826	ALL SCNS	515.42	491.85	492.08	51.53	56.05	58.95	55423.8	0.072	23.34	23.57
827	ALL SCNS	497.55	422.62	423.87	50.16	53.77	56.44	55450.6	0.121	73.68	74.93
828	ALL SCNS	483.13	355.65	357.61	49.54	52.98	54.87	55520.6	0.155	125.53	127.48
829	ALL SCNS	475.84	324.20	326.43	49.49	52.72	54.53	55442.5	0.174	149.41	151.64
830	ALL SCNS	468.85	289.27	291.68	49.37	52.54	54.53	55299.4	0.187	177.17	179.58
831	ALL SCNS	472.45	319.46	321.51	49.10	52.52	54.61	55658.8	0.175	150.95	152.99
832	ALL SCNS	477.58	350.37	352.25	49.51	53.00	55.03	55185.0	0.161	125.33	127.22
833	ALL SCNS	489.29	412.93	414.18	50.43	53.97	56.05	55230.6	0.130	75.12	76.37
834	ALL SCNS	507.71	482.34	482.57	51.49	56.18	58.39	55416.9	0.078	25.14	25.37
835	ALL SCNS	513.38	497.87	497.58	52.36	57.59	59.42	55389.4	0.064	15.80	15.52
836	ALL SCNS	530.48	529.35	529.61	54.33	57.05	60.97	-12.5	0.000	0.86	1.13
837	ALL SCNS	527.43	513.25	513.57	53.87	53.67	56.37	-12.5	0.055	13.87	14.18
838	ALL SCNS	528.11	500.17	500.51	54.03	53.82	56.42	-12.5	0.074	27.60	27.94
839	ALL SCNS	516.87	446.06	446.67	52.88	52.98	55.44	-12.5	0.112	70.21	70.82
840	ALL SCNS	505.51	382.75	383.57	52.31	52.59	55.13	-12.5	0.145	121.95	122.76
841	ALL SCNS	499.23	346.93	347.92	52.14	52.54	54.87	-12.5	0.159	151.32	152.30
842	ALL SCNS	493.92	317.09	318.18	51.94	52.49	54.93	-12.5	0.167	175.74	176.82
843	ALL SCNS	496.61	345.24	346.24	52.60	53.00	55.37	-12.5	0.156	150.37	151.37
844	ALL SCNS	500.52	374.65	375.51	53.46	53.85	56.13	-12.5	0.142	125.01	125.87
845	ALL SCNS	510.26	433.28	433.94	55.95	56.02	58.21	-12.5	0.112	76.32	76.97
846	ALL SCNS	525.37	499.04	499.42	60.17	60.04	62.17	-12.5	0.064	25.94	26.33
847	ALL SCNS	532.94	513.00	513.30	66.91	66.59	68.76	-12.5	0.056	19.64	19.95
848	ALL SCNS	542.08	528.41	528.78	79.36	78.93	81.00	-12.5	0.036	13.30	13.67
849	ALL SCNS	551.08	550.16	550.46	89.71	95.48	99.68	-12.5	0.000	0.62	0.92
850	ALL SCNS	589.25	560.02	559.93	51.23	55.31	58.16	45361.3	0.063	29.32	29.23
851	ALL SCNS	566.71	489.92	490.50	50.03	53.06	56.30	45397.5	0.104	76.21	76.80
852	ALL SCNS	557.08	483.60	484.21	49.71	52.85	55.58	45315.6	0.104	72.87	73.48
853	ALL SCNS	521.69	390.72	392.82	48.59	51.45	54.31	45296.3	0.148	128.88	130.98
854	ALL SCNS	500.45	349.70	351.89	48.41	51.27	54.11	45200.0	0.158	148.56	150.75
855	ALL SCNS	467.70	296.04	298.26	48.08	51.19	54.17	45371.3	0.172	169.44	171.66
856	ALL SCNS	447.20	294.14	296.26	48.31	50.91	53.90	45276.3	0.164	150.93	153.05
857	ALL SCNS	440.42	314.23	316.10	48.42	51.11	54.46	45322.5	0.152	124.32	126.19
858	ALL SCNS	437.49	360.51	361.75	48.77	51.70	54.91	45389.4	0.121	75.74	76.98

RESEARCH PROGRAM: BRUSH SEALS FOR CRYOGENIC APPLICATIONS TEST FACILITY: CCL - CELL2 BAROMETER: 14.268 PSIA

CONFIGURATION NO. 9 Single brush in position 1 with stubby rotor

FLUID: HYDROGEN

RDG	AVG SCANS	AVG PRESS STATION 1 (PSIA)	AVG PRESS STATION 2 (PSIA)	AVG PRESS STATION 5 (PSIA)	AVG TEMP STATION 1 (R)	AVG TEMP STATION 2 (R)	AVG TEMP STATION 5 (R)	AVERAGE SHAFT SPEED (RPM)	VENTURI 2 LEAKAGE RATE (LBM/S)	DELTA-P STA 1-5 (PSID)	DELTA-P STA 1-2 (PSID)
859	ALL SCNS	440.36	411.26	411.77	49.84	53.33	56.75	45293.8	0.077	28.60	29.10
860	ALL SCNS	451.11	425.47	426.01	49.87	52.39	55.53	35348.8	0.074	25.10	25.64
861	ALL SCNS	442.44	367.81	369.11	49.02	51.19	54.17	35302.5	0.120	73.33	74.63
862	ALL SCNS	432.42	304.56	306.35	48.48	50.60	53.67	35272.5	0.152	126.07	127.86
863	ALL SCNS	432.02	281.84	283.77	48.30	50.45	53.50	35310.0	0.161	148.25	150.19
864	ALL SCNS	429.80	256.09	258.12	48.32	50.48	53.69	35157.5	0.172	171.68	173.71
865	ALL SCNS	437.23	285.12	286.95	48.99	50.68	53.83	35374.4	0.160	150.28	152.12
866	ALL SCNS	442.55	317.88	319.52	49.25	50.96	54.06	35331.9	0.148	123.03	124.67
867	ALL SCNS	453.24	380.04	381.20	50.74	52.54	55.34	35331.3	0.115	72.03	73.20
868	ALL SCNS	467.56	439.55	440.09	53.69	55.59	58.55	35308.8	0.072	27.47	28.01
869	ALL SCNS	475.79	460.65	461.01	57.85	59.76	62.48	35367.5	0.049	14.79	15.14
870	ALL SCNS	496.92	467.09	467.36	49.92	52.30	59.62	25079.4	0.084	29.56	29.82
871	ALL SCNS	471.05	389.40	390.20	48.66	50.97	59.62	25078.1	0.128	80.84	81.65
872	ALL SCNS	413.61	277.33	279.59	47.33	49.11	57.84	25074.4	0.252	134.02	136.28
873	ALL SCNS	407.78	250.44	252.88	47.16	49.46	57.98	25055.0	0.261	154.90	157.34
874	ALL SCNS	403.04	227.55	229.99	47.07	49.03	57.85	25086.3	0.262	173.05	175.50
875	ALL SCNS	410.88	259.75	261.80	47.13	49.31	57.50	25080.0	0.255	149.08	151.14
876	ALL SCNS	423.63	297.22	299.13	47.22	49.31	56.52	25111.9	0.243	124.50	126.41
877	ALL SCNS	466.85	390.03	391.20	47.90	49.72	57.60	25088.1	0.199	75.65	76.83
878	ALL SCNS	496.71	470.99	471.22	48.77	50.56	58.40	25076.3	0.120	25.48	25.72
879	ALL SCNS	506.06	489.69	489.77	49.30	51.38	58.14	25117.5	0.094	16.29	16.38
880	ALL SCNS	507.41	492.49	492.56	49.95	51.12	58.56	15191.9	0.091	14.86	14.92
881	ALL SCNS	497.98	471.76	472.12	49.59	50.99	54.99	15261.3	0.121	25.87	26.22
882	ALL SCNS	467.15	386.34	387.32	48.70	50.03	57.79	15154.4	0.191	79.83	80.82
883	ALL SCNS	449.02	317.93	319.54	48.36	50.03	56.45	15172.5	0.223	129.48	131.08
884	ALL SCNS	440.02	286.31	288.03	48.41	50.18	57.04	15169.4	0.234	151.99	153.71
885	ALL SCNS	439.97	256.44	258.17	48.71	50.33	57.36	15181.3	0.246	181.80	183.53
886	ALL SCNS	452.06	301.36	302.89	49.50	51.12	58.33	15166.3	0.224	149.17	150.70
887	ALL SCNS	459.43	333.05	334.31	51.56	52.93	59.42	15143.1	0.208	125.13	126.38
888	ALL SCNS	476.27	399.14	399.98	55.23	56.34	63.64	15175.6	0.166	76.30	77.13
889	ALL SCNS	506.11	484.28	484.39	64.52	65.40	72.13	15203.1	0.097	21.72	21.83
890	ALL SCNS	502.23	485.83	485.65	52.52	52.29	59.91	-12.5	0.034	16.58	16.39
891	ALL SCNS	509.04	485.38	485.17	51.91	51.80	58.15	-12.5	0.044	23.86	23.65
892	ALL SCNS	494.92	416.85	416.94	50.59	50.38	58.13	-12.5	0.073	77.97	78.07
893	ALL SCNS	478.98	350.35	350.94	49.28	49.71	57.06	-12.5	0.089	128.04	128.63
894	ALL SCNS	472.92	322.67	323.44	49.19	49.77	57.10	-11.9	0.090	149.48	150.25
895	ALL SCNS	467.36	288.47	289.32	48.87	49.74	56.47	-11.3	0.091	178.04	178.89
896	ALL SCNS	471.59	317.57	318.20	48.77	49.54	56.06	-12.5	0.094	153.38	154.02
897	ALL SCNS	476.63	348.81	349.25	48.99	49.43	56.96	-12.5	0.095	127.39	127.82
898	ALL SCNS	488.70	415.69	415.86	49.71	49.61	56.40	-12.5	0.088	72.85	73.01
899	ALL SCNS	504.63	479.79	479.72	50.77	50.32	58.38	-12.5	0.056	24.91	24.85
900	ALL SCNS	511.79	498.47	498.23	51.51	50.78	59.55	-12.5	0.040	13.56	13.32
901	ALL SCNS	526.20	525.52	525.37	54.71	71.95	84.83	-12.5	0.000	0.84	0.68

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1996	Technical Paper

4. TITLE AND SUBTITLE

Brush Seals for Cryogenic Applications
Performance, Stage Effects, and Preliminary Wear Results in LN_2 and LH_2

5. FUNDING NUMBERS

WU–584–04–11

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135–3191

8. PERFORMING ORGANIZATION REPORT NUMBER

E–9474

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546–0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TP–3536

11. SUPPLEMENTARY NOTES

Responsible person, Margaret P. Proctor, organization code 5320, (216) 977–7526.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category 20

This publication is available from the NASA Center for Aerospace Information, (301) 621–0390.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Brush seals are compliant contacting seals and have significantly lower leakage than labyrinth seals in gas turbine applications. Their long life and low leakage make them candidates for use in rocket engine turbopumps. Brush seals, 50.8 mm (2 in.) in diameter with a nominal 127-µm (0.005-in.) radial interference, were tested in liquid nitrogen (LN_2) and liquid hydrogen (LH_2) at shaft speeds up to 35 000 and 65 000 rpm, respectively, and at pressure drops up to 1.21 MPa (175 psid) per brush. A labyrinth seal was also tested in liquid nitrogen to provide a baseline. The LN_2 leakage rate of a single brush seal with an initial radial shaft interference of 127 µm (0.005 in.) measured one-half to one-third the leakage rate of a 12-tooth labyrinth seal with a radial clearance of 127 µm (0.005 in.). Two brushes spaced 7.21 µm (0.248 in.) apart leaked about one-half as much as a single brush, and two brushes tightly packed together leaked about three-fourths as much as a single brush. The maximum measured groove depth on the Inconel 718 rotor with a surface finish of 0.81µm (32 µin.) was 25 µm (0.0010-in.) after 4.3 hr of shaft rotation in liquid nitrogen. The Haynes-25 bristles wore approximately 25 to 76 µm (0.001 to 0.003 in.) under the same conditions. Wear results in liquid hydrogen were significantly different. In liquid hydrogen the rotor did not wear, but the bristle material transferred onto the rotor and the initial 127-µm (0.005-in.) radial interference was consumed. Relatively high leakage rates were measured in liquid hydrogen. More testing is required to verify the leakage performance, to validate and calibrate analysis techniques, and to determine the wear mechanisms. Performance, staging effects, and preliminary wear results are presented.

14. SUBJECT TERMS

Brush seals; Cryogenic seals; Shaft seals; Dynamic seals; Liquid hydrogen; Liquid nitrogen

15. NUMBER OF PAGES

78

16. PRICE CODE

A05

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	